AN INTRODUCTION

TO

ZOOLOGY

THROUGH NATURE STUDY

WITH

DIRECTIONS FOR PRACTICAL WORK

(INVERTEBRATES)

BY

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FOREWORD

There are many different views as to what is of most value in education, but there are few teachers who will not agree that it is good for every one to know his or her way about in the world in which we live. And this is what a book like this makes for. It is not only that some acquaintance with the ways of animals is interesting and enriching, a joy in leisure-times; it is not only that even everyday Natural History is full of unsolved, brain-stretching problems which make it better than an unending serial story; there is a deeper value: that through a patient, precise, and sympathetic study of common animals we may reach a better understanding of ourselves and our place in Nature.

One of our poets exclaims:

> "A poor life this, if full of care
> We have no time to stand and stare,"

and the more we learn, the more profitable and the more delightful will our staring be. It will lead to a

> " . . . love exceeding a simple love of things
> That glide in grasses and rubble of woody wreck.'

And gradually we shall learn what cannot be learned in any other way. Towards this discovery this book is a good guide. I have used the first edition for many years and always with pleasure and satisfaction, for the qualities of accuracy and lucidity are conspicuous, and one cannot help enjoying the fresh air through its pages; there is a high standard of thoroughness and precision, but there is also sympathetic appreciation of the ways of living creatures.

I wish the new edition the success it undoubtedly deserves.

J. ARTHUR THOMSON.

August 1923.

PREFACE TO FIRST EDITION

It is desirable, perhaps, to give some reason for adding another book on Natural History to the many that already exist, and to indicate in what way the book is intended to be used.

The danger of the multiplication of small text-books is that they may conceivably be used in place of that first-hand investigation which must form the basis of all scientific work; nevertheless, so long as the time allotted to Natural History is as limited as it is in the ordinary curriculum of school and college in this country, it is necessary to use to the best advantage the hours which teacher and pupils spend together, and I suggest that this time can at first be most profitably spent in practical work, during which the teacher directs and supplements the observations of the class, leading his pupils to reason about the facts they observe, and to record them by means of clear accurate drawings with brief explanatory notes.

This method, however, leaves little time for ordinary note-making in which the facts are woven into a coherent whole that may be used for future reference and revision; and it is partly for this reason that I venture to think there is room for such a book as this, which, as well as giving directions for the practical study of a number of different types of living animals, gives also a general account of their structure and life-history, and indicates their relationship to other creatures, so that they do not remain as isolated types in the student's mind, but fall into place as representatives of the varied branches of the animal kingdom. It is, however, strongly recommended that *the practical study should always*

precede the reading of the chapter dealing with the type under investigation.

It is hoped that this book may be of use to pupils in the senior classes of secondary schools; to the students of "Nature Study" in Training Colleges; perhaps also to those entering upon a systematic course of Zoology such as that in preparation for University examinations, who may feel the need of some help in gaining a preliminary, first-hand knowledge of the *living* creatures which, in their academic course, they usually meet only as dead laboratory specimens; and finally to those students, working alone, who may desire some guide as to what path to follow in the wide field of Natural History, and for whose sake numerous references are given to books where fuller information may be obtained.

The book deals almost entirely with the habits and external structure of common British Invertebrate animals; occasionally a few points of internal structure have been touched upon, either because a knowledge of them was necessary for the explanation of the external phenomena, or because they must be known before the relationships of the various types of animals described could be appreciated. Microscopic structure is only given in a few of the first types, where it seemed to be desirable in order to illustrate some of the stages in the evolution of a more complex form of body from the simple unicellular form.

The statement given above explains to some extent why this book has been *published*: why it has been *written* is another matter—connected not so much with such things as examinations and the needs of classes of students, as with the delight of merely watching living things, of trying to trace out their strange life-histories, and then of comparing notes with what other investigators have recorded. The author is, however, very conscious that in a book of this kind, which skims over such a wide field, there will be many omissions, and also observations may be recorded in it which ought first to have been further verified; notification of errata or of facts elucidating doubtful points will therefore be most gratefully received.

In conclusion, I wish to express my thanks to Miss Violet Sheffield for the skill and care with which she has carried out my directions in the preparation of the illustrations, an

exceptionally difficult task, as a very large number have been drawn from the living creatures in order to reproduce as far as possible their characteristic appearance in life.

I am indebted to Messrs. Macmillan and Co. for permission to reproduce Figs. 34, 46, 55, 56, 57, 59, 62, 63, and 325 from the *Cambridge Natural History*; Figs. 6, 7, 18, 26, 30, 31, 58, 61, 64, 65, 111, and 129 from *A Text Book of Zoology* by T. J. Parker and W. A. Haswell; and Figs. 192 and 206 from *Aquatic Insects* by Professor Miall; also to Messrs. Cassell and Co. for Fig. 88 from *The Outdoor World* by W. Furneaux, and Fig. 320 from *Eyes and No Eyes* by Mrs. Fisher; to the Trustees of the British Museum for Figs. 41, 119, and 135, taken from the Guides to the Museum; to Messrs. A. and C. Black for Fig. 155 from *A Text Book of Zoology* by O. Schmeil; to Messrs. Newnes for Figs. 136 and 138 from *Flashlights on Nature* by Grant Allen; to Messrs. Methuen for Figs. 316 and 317 from *The Bee People*; and to the Columbia University Press for Figs. 337-341 from *Ants* by W. M. Wheeler.

Finally, my heartiest thanks are due to Miss Collins, the Principal of the School of Nature Study and Gardening, Clapham, near Worthing, for the many beautiful specimens with which she has provided me; to Miss M. E. Everett and Miss G. Rowland for their very valuable assistance in the criticism and correction of the proof-sheets; and to Miss Mary Bulkley for the careful Index which she has made.

R. B. J. LULHAM.

August 1913.

THE FROEBEL EDUCATIONAL INSTITUTE,
COLET GARDENS, WEST KENSINGTON, LONDON.

PREFACE TO SECOND EDITION

In this second edition I have endeavoured to bring the book up to date, and have also added some fresh matter—*e.g.* the chapter on Cephalopods, a few additional pages on Echinoderms, etc. There are also twenty-six extra illustrations, and appendices in which are given practical details as to how to aerate an aquarium and how to make suitable cases in which to keep ground-inhabiting creatures, such as Dor-beetles, Ants, Earwigs, etc.

I am indebted to Mr. Hugh Main for permission to describe his Subterrarium and Formicarium; to the trustees of the Horniman Museum for the appendix on "How to Aerate an Aquarium"; to the authorities at the British Museum (Natural History), who have kindly given me information on several points, and to the trustees, who allowed me to reproduce Figs. 103, 104, 107, 108 and 110 from the *British Museum Guide to the Fossil Invertebrates*; to Messrs. Macmillan for permission to reproduce Figs. 39, 102, 134, 176, 350, from the *Cambridge Natural History*; Figs. 21, 42, 100, 105, 106, 109, 162, from *A Text Book of Zoology* by T. J. Parker and W. A. Haswell; and Fig. 20 from *Zoology for Secondary Schools in India* by W. Rae Sherriffs; to Messrs. Upcott Gill for Figs. 249 and 250 from *British Dragon Flies* by W. J. Lucas; and to Messrs. Longman for Figs. 37 and 38 from *The Sea Shore* by W. S. Furneaux.

Also I thank Miss Mildred Bulkley for her skilled help in correcting the proofs and revising the Index.

Finally, I wish to express my warm gratitude to Professor J. A. Thomson for the encouragement he has given me and his kindness in writing a "Foreword" for this new edition of the book.

R. B. J. LULHAM.

August 1923.

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PREFACE TO REPRINT, 1927

In this reprint I have merely altered a sentence here and there in an endeavour to increase clearness of expression, and, in some cases, to correct errors or to bring the facts up to date in the light of recent investigations. I should like here to acknowledge with gratitude the assistance I have had from Dr. Fraser of University College, London, and Miss Hett of Bedford College, London, who have given me most helpful criticism on many points.

R. B. J. LULHAM.

August 1927.

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Ἐν πᾶσι γὰρ τοῖς φυσικοῖς ἔνεστί τι θαυμαστόν.

INTRODUCTION AND GENERAL CLASSIFICATION

ZOOLOGY (Gr. *zoon*, animal; *logos*, discourse) is the study of animal life as distinguished from *Botany* (Gr. *botane*, a herb), the study of plant life, the two together forming the science of living organisms known as *Biology*.

It is well to bear in mind from the first that these two branches of the tree of life, though bearing such markedly different forms at their apices, unite at their base; the animal and plant characteristics become merged together, so that in the simplest forms it is often difficult, if not impossible, to distinguish with certainty as plant or animal the little speck of living matter which constitutes the whole organism.

General Classification. Nomenclature. If we consider all the members of the animal kingdom known to us, the great variety of them is remarkable, and, at the same time, no less remarkable is the fact that when we come to examine their structure closely we find they can be grouped in quite a small number of primary groups, with a peculiar type of structure characteristic of each; these primary groups of animals are known as *Phyla* or sub-kingdoms. Most of these phyla contain an enormous number of forms which, though having certain underlying characters in common, in many ways display great variety, and so we subdivide each phylum into *Classes*, the members of each class being alike in certain secondary characteristics which distinguish them from the other classes of the same phylum.

Similarly we divide each class into *Orders*, each order into *Families*, each family into *Genera*, and finally each genus into *Species*. The individuals included in one species will display only those slight variations which we are accustomed to

note amongst individuals of the same kind, variations which are not constant from generation to generation.

Sometimes, however, these groups may still contain forms with so much constant variation of structure that further subdivision may be desirable; *e.g.* an order is very often divided into *sub-orders* or *tribes*, and then these into families; sometimes it is even necessary to distinguish separate *varieties* of one species.

This system may be more clearly understood if we take a special example and attempt to classify it. Let us take, *e.g.*, the common, well-known Large Cabbage White Butterfly. We know this butterfly by its size and colouring, the white wings being marked in a special way with dark-brown pigment (Fig. 168), and also we know its caterpillar by its special form and colouring (Fig. 164). There are other very similar white butterflies, *e.g.* the "Small White" and the "Black-veined White," but these two are obviously different "kinds" of butterfly, as we say, for they differ slightly, but constantly, in size and in details of marking from the "Large White," also the habits and external appearance of their caterpillars are different; hence, whilst popularly we call them all "White Butterflies," we distinguish them as Large White, Small White, and Black-veined White. Such popular names, however, vary in different countries, and so it is convenient to have Latin or Greek equivalents which are used by all observers, irrespective of locality. Scientifically, therefore, we include all these three forms in one genus, the genus *Pieris*, and we express our sense of the differences between them by giving each a *specific* name in addition. The Large White we call *Pieris brassicae*, the Small White, *Pieris rapae*, and the Black-veined White, *Pieris crataegi*. This method of calling each kind or species of creature by a double name was introduced by Linnæus, and it has proved a most convenient one.

Now there are several other genera of butterflies that resemble *Pieris* in general form of wing, and in the general habits and form of caterpillar and chrysalis; *e.g.* the Orange Tip Butterfly (*Euchloë cardamines*) and the Brimstone (*Gonepteryx rhamni*) (see p. 249); these, therefore, although too dissimilar to be included in the same genus, are all grouped together in one *family*, the Pieridae Then again there are many different

families of butterflies which differ in minor points, but which are all alike in having club-shaped antennae, in holding their wings vertically when at rest, and in the general form of the pupa—characters in which they differ from those forms we call Moths, which have typically feathery antennae pointed at the tip, fold their wings horizontally over their backs when at rest, and have dark, oval-shaped pupae. On the other hand, Butterflies and Moths are alike in such important points as the structure of their mouth-parts, the presence of minute scales over the wing-surfaces, and in the complete metamorphosis characteristic of their development; they are therefore grouped together in the *order* Lepidoptera (Gr. *lepis*, scale; *pteron*, wing), though butterflies are separated in the special *sub-order* Rhopalocera (Gr. *rhopalon*, club; *keras*, horn).

Then again, in the general structure of the body, in the number of legs present, in the possession of wings, and in their method of breathing, Butterflies and Moths (Lepidoptera) resemble Beetles, Dragon-flies, Bees, Flies, and Cockroaches; all these forms, therefore, are grouped together in the *class* Insecta.

Finally, Insecta resemble Spiders and Crustaceans (Lobsters, Crabs, etc.) in having a hard shelly covering to the otherwise soft body, and in having jointed limbs; hence all these forms are included in the *phylum* Arthropoda, one of the primary divisions of the animal kingdom.[1]

The position amongst animals which we assign to the Large White Butterfly may therefore be summarised thus:—

Kingdom—*Animalia.*
Phylum—*Arthropoda.*
Class—*Insecta.*
Order—*Lepidoptera.*
Sub-order—*Rhopalocera.*
Family—*Pieridae.*
Genus—*Pieris.*
Species—*brassicae.*

This scheme of classification is of course dependent on our present knowledge, and is provisional only. The aim of zoologists in making such a scheme has been to try to

[1] Only certain of the obvious external characteristics have been considered in this classification, but it should be noted that it is based also on similarity of internal structure.

express what seem to be the natural relationships of the animals classified, so far as we can at present determine them with our still imperfect knowledge of the course of evolution which has resulted in all the manifold forms of life on the earth.

The twelve primary divisions, or phyla, of the animal kingdom at present recognised are :—

I. Protozoa (unicellular microscopic forms).
II. Porifera (Sponges).
III. Coelenterata (Hydra, Jelly-fish, Sea-anemones).
IV. Platyhelminthes (Flat-worms, Liver-fluke, etc.).
V. Nematoda (Round-worms, unsegmented).
VI. Annelida (Ringed Worms, *e.g.* Earthworm).
VII. Echinodermata (Starfish, Sea-urchin, etc.).
VIII. Polyzoa[1] (Sea-mats, *e.g.* Flustra, Bugula, etc.).
IX. Rotifera (Wheel Animalcules).
X. Mollusca (Snails, Mussels, etc.).
XI. Arthropoda (Crustaceans, Spiders, Insects).
XII. Chordata (all vertebrate animals).

In the following pages, types of all these phyla will be described, with the exception of the last, the Chordata, the phylum which includes all Fishes, Amphibia, Reptiles, Birds, and Mammals, such a vast and important assemblage of forms that they are left for fuller treatment than is possible in this volume.

[1] The Polyzoa should perhaps be united with the *Brachiopods*, the Lamp-shells, in a phylum Molluscoidea, but in this book only the Polyzoa are described.

CHAPTER I

PHYLUM I.: THE PROTOZOA

THE Protozoa are the simplest animal forms known; in them the whole living body consists of a single speck of the jelly-like living substance, Protoplasm, the body being so minute as to be very frequently invisible to the naked eye. Because of their simple delicate structure and their lack of special organs for carrying on the different vital functions of the body,[1] these Protozoan organisms are able to exist only under special limited conditions, and are nearly all to be found living in water, fresh or salt, though some are parasitic in the tissues of other animals.

In this group are included all the naked unicellular forms such as the freshwater Amœba and Vorticella, and also those marine forms such as Globigerina, which secrete round their bodies calcareous shells.

Type: **The Amœba, or Proteus Animalcule.**

This simplest of animals is unfortunately so small that a microscope is necessary for its examination. However, an understanding of certain points in its structure, and of its vital processes, is so helpful as a basis for the study of more complex forms, that it is well, if possible, to acquire some practical knowledge of it when beginning the study of different types of animal life.

Amœbae are to be found very abundantly in the mud at the bottom of most ponds, but as each individual is at most only about $\frac{1}{100}$th of an inch in diameter, a microscope with a high magnifying power is needed to render its structure visible.

[1] Recent research, however, reveals a much more complicated structure than was formerly realised.

Structure. When so magnified, it is seen as a round or more or less irregular body, of a semi-fluid consistency, the greater part of it being finely granular, whilst round the margin is a clear non-granular border. It is colourless or slightly greyish in tinge, but within the transparent body can be seen various opaque food particles which have been absorbed. The body is continually changing its shape, sending out a process now in one direction, now in another, or, if touched, withdrawing all its processes, and becoming round in outline.

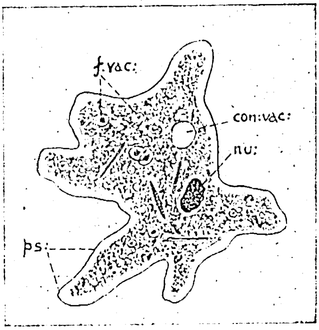

FIG. 1.—*Amœba proteus.* × 200. *nu*, Nucleus; *ps*, pseudopodium; *con. vac*, contractile vacuole; *f. vac*, food vacuoles.

The substance of which this body is formed is that *Protoplasm* of which Professor Huxley wrote as "The Physical Basis of Life";[1] for it is the fundamental substance which is present in *all* living things, be they plant or animal, and which, so far as we know, alone renders possible the phenomenon which we call physical life.

On carefully examining this protoplasmic body two structures can usually be readily detected, embedded within it. There is a small, oval or round, darker mass known as the *nucleus* of the protoplasm. In chemical composition this is very similar to the rest of the living protoplasm, but it is denser, and it performs special important functions within the cell, controlling apparently the nutritive and reproductive processes.

Then, after a little search, a clear round space can also be seen, which will disappear suddenly and then slowly form again, thus gaining the name of the *contractile vacuole.* When visible, the space is filled with a watery fluid; when the vacuole contracts, this fluid is driven in radiating streams out of the protoplasmic body.

Such a mass of living protoplasm with its nucleus is known as a *cell,* and Amœba is therefore said to consist of one cell, or to be unicellular.

[1] Lay Sermon in *Collected Essays*, vol. i.

The Nature of Protoplasm. By chemical analysis the constituent elements of which this protoplasm is formed can be determined. It consists of carbon, hydrogen, oxygen, nitrogen, and sulphur, with minute traces of phosphorus and other elements, but by no method of chemical synthesis yet known to us can we cause these elements to reunite to form living protoplasm once more. The secret of life is hidden from us.[1]

Such living protoplasm, however, exhibits certain definite phenomena which, though we know not their ultimate origin, we learn to recognise as characteristic of life—the phenomena, namely, of irritability, or power to respond to stimuli, of movement, of absorption and digestion of food, of respiration and excretion of waste matter, and, finally, of growth and reproduction. Even such an apparently simple organism as Amœba exhibits all these vital phenomena.

Locomotion. In Amœba, movement appears to consist of the streaming of the protoplasm towards one point, so forming a long process, the rest of the protoplasm gradually flowing after it in the same direction; each such process is known as a "pseudopodium" or "false-foot"; in this manner the Amœba can make its way over the mud and debris amongst which it lives.

Nutrition. The absorption of food takes place by a modification of the process of motion. Two pseudopodia are formed by the streaming outwards of the protoplasm, and these gradually surround the object desired, which consists usually of some very minute animal or vegetable organism. The processes fuse round the food particle, so that, together with a little drop of water, it is actually engulfed in the protoplasm, forming a "food vacuole." The soft, soluble parts of the food are then dissolved, probably by some digestive juice secreted by the protoplasm, and so the food is rendered capable of absorption and assimilation, new protoplasm being built up from it. Undigested solid portions of food are got rid of by the simple flowing of the protoplasm away from the matter to be rejected, just the reverse process from that by which the food was at first engulfed.

[1] For account of experiments to illustrate the nature of protoplasm, refer to *Investigations on Microscopic Foams and on Protoplasm*, by O. Bütschli, English translation by E. A. Minchin (A. & C. Black) (now out of print).

Excretion. The protoplasm in a living body is in a constant state of change; new protoplasm is continually being built up by the assimilation of food, and then this very complex compound breaks down again into simpler compounds, which are finally excreted from the body in gaseous or liquid form. One of the chief gaseous excreta is carbon dioxide. This is formed by the union of the carbon of the disintegrating protoplasm with the free oxygen which has been dissolved by the surrounding water from the air above, and has passed from the water into the protoplasm of the body. The carbon and oxygen combine in the proportion of one part of carbon to two of oxygen to form carbon dioxide, the chemical composition of which is expressed by the formula CO_2. This gas is given off from the surface of the protoplasm and disperses, dissolving in the surrounding water. A change is therefore continually taking place in the gaseous contents of the water in which the Amœba lives, the amount of dissolved oxygen lessening and being replaced by carbon dioxide. This oxidation of the carbon of the disintegrating protoplasm by the oxygen from the surrounding medium (be it air or water), and the resultant excretion of carbon dioxide, is the process known as *Respiration*: the essential nature of the process is the same in all animals and plants, though—owing to the complexity of the bodies of the higher animals—special organs have been evolved in them for facilitating the interchange of gases.

The simpler nitrogenous substances, which are also formed when protoplasm disintegrates, probably accumulate in liquid form in the contractile vacuole, and are expelled from the body when this suddenly contracts.

Growth and Reproduction. If the assimilation of food is more rapid than the disintegration of the protoplasm and the excretion of waste matter, then *Growth* results, but this is always limited in extent, the limit being probably reached when the bulk of the body is so great, compared with its surface, that any further enlargement of it would demand a greater increase in the absorption of oxygen and of food than is possible to the absorbent superficial layer. Having reached its full limit of size, the Amœba proceeds to divide into two; the nucleus first divides, and then the whole body lengthens out, the two daughter nuclei moving apart; finally a constric-

tion appears in the protoplasm, which gradually deepens and separates it into two halves, each of which contains half of the original nucleus. In this way, by "simple fission" of the parent organism, *reproduction* has taken place.

Each daughter Amœba lives exactly as did the parent cell, finally dividing to form two new Amœbae, and so the life of the first individual never ceases, but becomes extended in the separate lives of its descendants. There seems no necessary natural end to the life of such a simple form, though death must frequently occur through an accident, such as the drying up of the necessary water environment or the digestion of the Amœba by another, higher form.

Resting Stage. An Amœba can live only under certain conditions as to temperature, moisture, and air supply. If external conditions become unfavourable to its active life, it can protect itself by secreting from the superficial layer of its protoplasm a horny or chitinous substance, which hardens and forms a thin shell or "cyst" over it; within this it can remain passive until conditions are favourable again, it then ruptures the cyst and resumes its normal activity. Before this, repeated division may occur within the cyst.

Temporary Fusion. Two Amœbae, on meeting, may fuse together for a time and then separate, and it is thought that as a result of the stimulus given by such fusion they afterwards carry on their separate lives more vigorously, for this is known to be the case in some other forms.

From the above observations we see that this very simple unicellular form, which, though to a certain degree sensitive to external stimuli, has no definite sense perceptions and no organs of any kind, yet exhibits all the main phenomena of life. The very simplicity of its structure and meagreness of its requirements seem to further its success in the struggle for existence.

Learning by Experience. It seems that an Amœba can learn by experience, for if it is given a grain of sand it will at first engulf it as if it were digestible food matter, and this may happen several times in succession, but finally it will ignore such a particle as if it had become aware that it was indigestible and useless.[1]

[1] See also Dr. Jenning's experiments on the unicellular *Stentor*, quoted in *Study of Animal Life*, by J. A. Thomson 1917.

Genus and Species. There are several species of Amœbae differing in size and in the character of the nucleus and in other small points, but all so similar in their main characters that they are called by the same *generic* name, *Amœba*.

The *species* of Amœba described above is *Amœba proteus*, whilst another form, with shorter pseudopodia and several nuclei, is distinguished as *Amœba quarta*.

Unicellular Forms which secrete a Shell.

Many forms closely allied to Amœba have taken one step upward on the ladder of life, by acquiring the habit of secreting round their bodies a covering which is not temporary, as in the case of the Amœba's "cyst," but is permanent, and is of such a form that, whilst allowing all vital processes to continue unchecked, it serves as some slight protection to the soft protoplasmic body. These protective "shells" are usually of calcium carbonate (chalk), or of silica, and they are perforated by one or more pores through which the protoplasm can freely project; incidentally they exhibit a wonderful variety and beauty of form.

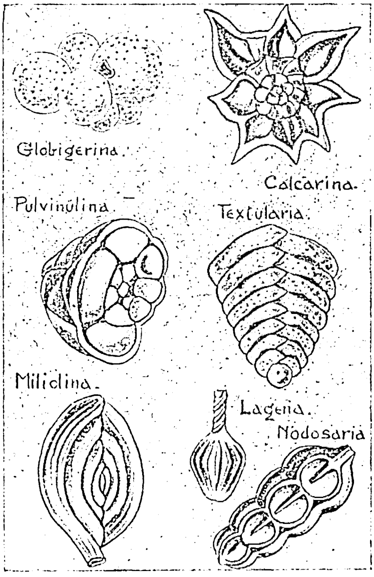

FIG. 2.—Shells from a Chalk Formation. × 300.

Formation of Chalk Rock. A few of these are shown in Fig. 2. The special forms illustrated are all taken from sea-water forms, which, when alive, float freely in the water, but at death sink slowly to the bottom of the sea, where their chalky shells may accumulate, year after year, for

many centuries, forming a thick layer, such as is now being deposited on the bed of the Atlantic Ocean where this is not at a greater depth than 12,000 feet.[1]

Such a deposit, owing to the continuous pressure of the ocean above, gradually becomes consolidated into a hard chalk rock. In many cases, after long ages, it has happened that such a rock has been raised above the sea-level by the gradual change in relative altitude of land and sea-bottom, with the result that the latter now forms a white chalk cliff or down, such as those to be seen along many parts of our coasts.[2]

Such chalk rock, if it should be exposed to extreme heat as well as pressure, such as might be produced by volcanic action, becomes crystalline, and the rock known as marble is formed.

It is wonderful to think of the constant circulation of material that is always going on, and resulting in a continual change of the face of the earth. The rain drives down through the air, dissolving as it descends some of the very soluble gas carbon dioxide, which, owing to the respiration of all living things, is always present in the air. By virtue of the carbonic acid so formed, the water as it trickles through the earth is able to dissolve little particles of chalky material (calcium carbonate) and other solid substances present in the earth, and even to wear away hard solid rock. Finally the water with its dissolved matter may find its way into a river, and be carried far out to sea. Here the sun's rays beat down on the surface of the water and draw the water-drops up again out of the ocean into the air, changing them from visible form to invisible, from liquid to gas or vapour. But it is the pure water alone that rises in the air; all that it carried has to be left behind, and so the sea accumulates an increasing amount of dissolved matter, and consequently tends to get salter and salter. The little, soft-bodied, unicellular organisms, however, which live in this salt water, need to make for themselves protective cases, and they have learnt to absorb the salt water and take from it some of the dissolved materials, from which the living protoplasm of their bodies is able to build up their little shells

[1] At a greater depth than this only siliceous shells are found, for the delicate calcareous shells become dissolved by the carbonic acid in the water which has a greater solvent power at the increased pressure resulting from the greater depth below the surface.

[2] See Huxley on "A Piece of Chalk," *Collected Essays*, vol. viii.

of chalk or silica, and in so doing they help to prevent the water from getting too dense for animals to live in. Then, as explained before, these shells accumulate for thousands of years, and form the chalk rock, which may again form dry land, and again, by the action of water, be worn away and carried back to the sea; and so the cycle goes on.

Unicellular Forms which possess Cilia or Flagella.

Other relations of the Amœba have adopted a more active means of protecting themselves from danger, for, instead of or as well as a protective coat, they have developed certain very simple organs of locomotion, consisting of delicate threads of protoplasm, known as "cilia" (*cilium*, an eye-lash), which project from the general surface of the body, and by their rapid vibration up and down propel the whole body forward in the water. Others have one or more longer processes known as "flagella" (*flagellum*, a whip), which lash the water, sometimes with a wheeling motion.

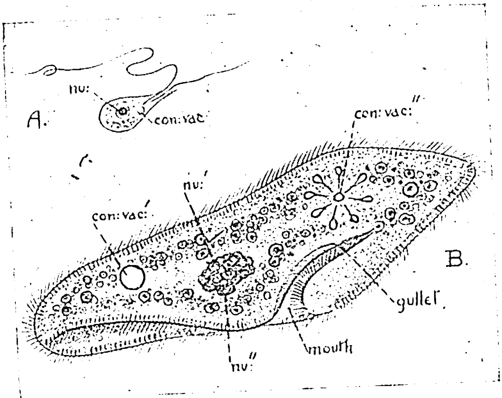

FIG. 3.—*A*, *Bodo saltans*; *B*, *Paramoecium*. × 240.
nu', Nucleus; *nu''*, micro-nucleus; *con. vac'*, contractile vacuole forming; *con. vac''*, contractile vacuole discharging.

The Springing Monad. Some forms have a pair of such flagella, as in the Springing Monad *Bodo saltans* (or *Heteromita rostrata*) (Fig. 3, *A*), a very minute form, found in

water in which organic matter has been allowed to decay. Others are covered by a continuous coat of cilia, as in the Slipper Animalcule *Paramoecium* (Fig. 3, *B*). This genus is

The Slipper Animalcule. also more highly organised than Amœba, for it has a more definite form and a special funnel-like depression at one point of the body, through which alone food is absorbed, and which functions, therefore, as a mouth. *Paramoecium* is an interesting organism to study. It is larger than most unicellular organisms, being just visible as a speck to the naked eye; a full account of it is to be found in most elementary text-books of zoology,[1] and any further account of it will be omitted here, since Vorticella, the next unicellular form to be studied, amply illustrates the complexity of differentiation and life-history possible in these simple forms; also it is so very commonly met with by the student of pond-life that a study of it is inevitable.

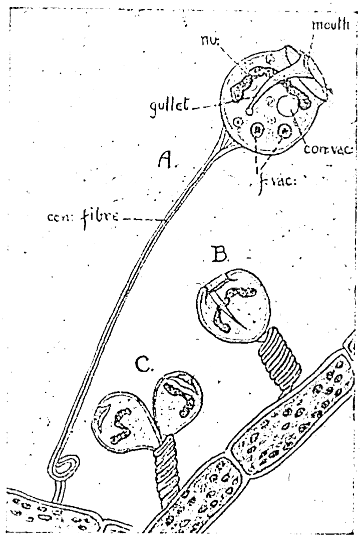

FIG. 4.—*Vorticella*, attached to a Water-weed. × 30.

A, A partly expanded bell; *B*, a contracted bell; *C*, a bell dividing by simple fission; *nu*, macro-nucleus; *con. vac*, contractile vacuole; *f. vac*, food vacuoles; *con. fibre*, contractile fibre of stem.

Type: Vorticella, the Bell Animalcule.

Habitat. General Appearance. In examining water-weeds or other objects taken from a pond there are very frequently to be seen, with the naked eye, minute, colourless, bell-shaped bodies, that constantly seem to float away from the surface of the weed, and then, on the slightest vibration of the water, to be suddenly drawn back again by a delicate thread which contracts into a thick, spirally-coiled stalk. This organism is Vorticella, the Bell Animalcule.

[1] See *Elementary Biology*, by T. Jeffery Parker.

There are three chief points in which Vorticella is seen at once to differ from Amœba: it is permanently fixed by this contractile stalk; the body does not exhibit the same curious irregular changes of shape as in Amœba, for although the protoplasm contracts and expands, it never sends out irregular pseudopodia but keeps its definite shape; and, finally, round the free margin of the "bell" there is a circle of fine cilia which by their vibrations keep the surrounding water in constant motion.

Structure. For full investigation of the structure of the body a compound microscope will be needed. The Vorticella, still attached to the weed, should be mounted in a drop of water, carefully covered with a cover-slip, and examined under the low power of the microscope. It will then be seen that, though the body consists of one single mass of protoplasm, this protoplasm is differentiated in different parts of the body; also it is surrounded externally by a delicate, transparent, limiting layer, the *cuticle*, which was not present in Amœba.

In the "bell" itself the protoplasm is differentiated into an outer, denser, cortical portion, and a less dense central "medulla." Lying in the medulla is a large horseshoe-shaped nucleus, the macro-nucleus, and also a small round nucleus, which seems specially concerned with the reproductive processes (see p. 17). At the free end of the bell the protoplasm is thickened to form a slight rim round the edge, and within this, but separated from it by a depression except on one side, the protoplasm rises obliquely, forming the surface plate known as the *disc* (see Fig. 5). This disc looks rather like a lid hinged at one side, but it is really continuous with the protoplasm of the rest of the body. Just at the highest point of the disc there is, between it and the projecting rim of the bell, a deep tubular depression, which runs right down into the centre of the bell; through this, food is passed into the

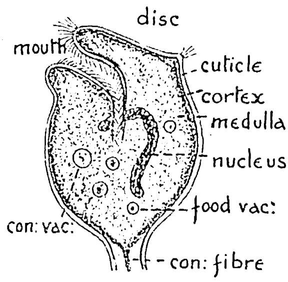

FIG. 5.—Optical Magnified Section of Vorticella to illustrate the union of Disc and Bell.

protoplasm, and hence it is called the *gullet*, and the open upper end of it is the *mouth*.

Nutrition. The food consists of minute particles of animal and vegetable matter, suspended in the surrounding water; it is driven into the mouth by the movement of the cilia, which are attached in a continuous single row along the margin of the disc, round into the inner margin of the rim and down the gullet. The regular lashing of this spiral of cilia causes a little whirlpool in the water which is driven down the gullet, and small globules of water containing food particles pass into the protoplasm, forming small vacuoles, inside of which the food is digested. These vacuoles pass through the protoplasm, and finally once more reach the gullet, into which any indigestible particles are ejected, to be carried away by the water.

Excretion. Here, as in Amœba, there is a large contractile vacuole, by means of which liquid excreta are got rid of. The process of *Respiration* takes place over the whole surface of the body.

Response to Stimuli. Movement. Vorticella is exceedingly sensitive to any contact-stimulus; directly it is touched the bell contracts, drawing down its disc and cilia, and becoming almost globular; at the same time, the stalk contracts into a tight spiral (Fig. 4, *B*), thus bringing the bell close down to the object to which the stalk is attached. The power of contractility of the stalk is concentrated in a special strand of protoplasm that can be seen in the extended stalk, running round inside the cuticle in a very open spiral (Fig. 4, *A*). On contraction this fibre becomes much shorter and thicker, thus drawing the coils of its spiral close together, and throwing the elastic cuticle into corresponding folds (Fig. 4, *B*).

Such a differentiated portion of protoplasm, having this power of contracting in a definite direction, causing definite movements of the body attached to it, is essentially a *muscle*, so that the "contractile axial fibre" of the stalk may be looked upon as a foreshadowing of the muscular system which becomes so complex in higher animals.

Reproduction. As in Amœba, Vorticella can reproduce by the simple fission of the body into two, the cleft beginning at the free surface, and spreading downwards to the base of the bell; the fission does not, however,

involve the stalk. One of the two daughter bells, whilst still attached to the parent stalk, develops a circlet of cilia near its base; it then breaks away and swims off, but finally settles down, probably at some distance from its parent, and becomes attached by its basal end to some submerged object. It then loses its recently acquired cilia and its base elongates, forming a long contractile stalk; thus it acquires its adult form.

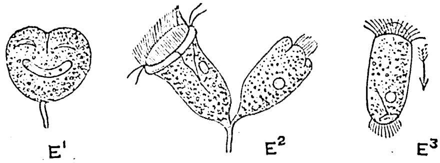

FIG. 6.—Vorticella. (After Saville Kent.)

E1, The beginning of binary fission of a bell; E2, completion of the process; E3, the barrel-shaped new individual swimming away. × 30.

Besides this simple method of reproduction there is another, which is not in the first place a process of multiplication, but a fusion of two individuals into one; this fusion, which is known as conjugation, results, however, in increased vital activity and more rapid multiplication by fission (compare Amœba, p. 9).

Conjugation. As a preliminary to the process of the conjugation of two individuals, we find that a Vorticella bell divides into two unequal parts, and that before separating from the parent stalk one of these daughter bells may divide again into from two to eight parts. In either case the smaller zooid or zooids so formed develop a basal circle of cilia, and become detached, free-swimming, barrel-shaped bodies (Fig. 7).

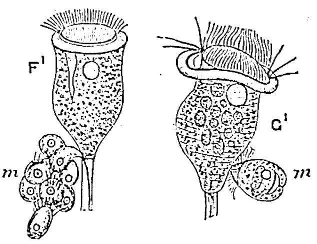

FIG. 7.—Vorticella. (After Saville Kent.)

F1, A bell dividing to form one daughter bell and several microgametes (*m*); G1, early stage in the fusion of a microgamete (*m*) and a macrogamete.

After swimming for some time, one of these small bodies attaches itself near the base of the bell of a stationary Vorticella, and, after a complicated series of changes has taken place in the nuclei of the two, it is absorbed into the stationary bell, complete fusion of the protoplasm and of

the smaller nuclei of the two bodies taking place (the large nuclei break up and disappear before fusion).[1]

Such a process of permanent fusion is known as *conjugation*, and the conjugating bodies are called *gametes*. Since they are of two sizes, they are distinguished as the *macrogamete* and the *microgamete*, but in the case of Vorticella it is to be noted that the macrogamete is merely the ordinary Vorticella bell, whilst the microgamete is a specially differentiated body. After the conjugation, as has been already said, multiplication by simple fission goes on with increased activity.

The differentiation seen in Vorticella between the large passive macrogamete and the small active microgamete is one that is retained in the female and male gametes of the more highly organised multicellular forms, where, however, the gametes do not consist of entire individuals, as is frequently the case in unicellular forms, but only of special cells differentiated in the body of each individual for the purpose of such fusion. The fusion, moreover, results in the formation of a new separate organism, arising from each pair of fused gametes (see Hydra, p. 30).

Resting Stage.

Occasionally Vorticella may surround itself with a protective "cyst," and remain dormant within it for some time, and such encystment may be followed, though only rarely, by the breaking up of the protoplasm within the cyst into a number of small ovoid bodies known as *spores*.[2] Each of these spores develops a single circlet of cilia and, breaking free, swims away, sometimes multiplying by fission, but eventually settling down—as in the case of the free bells formed by simple fission—growing a stalk, and gradually becoming a normal individual with stalk, bell, disc, gullet, and all the other characteristics of an ordinary Vorticella. This is a simple case of *development*, the term used to signify the gradual growth of the adult form from a germ unlike itself.

Colonial Forms.

In some closely allied forms—*e.g.* the common freshwater *Carchesium spectabile*, in which the structure of each individual is very like that of Vorticella—when fission takes place, it involves the stalk also, to some extent, and further, the daughter forms or

[1] See Saville Kent's *Manual of the Infusoria*, vol. ii. pp. 669 and 670 (London, 1882).

[2] Allmann, *Q.J.M.S.*, New Series, vol. xii., 1872, p. 393.

zooids all remain attached to the parent; in this way a branching colony of forms results, each individual, however, being quite independent of the others, so far as all its vital processes are concerned (Fig. 8). In *Carchesium* all the individual zooids are similar in size and shape, but in some other such compound organisms or colonies there is a distinct division of labour amongst the individuals, some being concerned only with the nutrition of the colony, whilst others are mouthless, have a basal circlet of cilia, and are concerned only with its reproduction and dispersal. These latter forms break away from the colony, and after a free-swimming period settle down and develop into ordinary nutritive individuals, which by fission give rise to new colonies. Such a form, with two kinds of individuals in the colony, is seen in the genus *Zoothamnium* common in sea-water.[1]

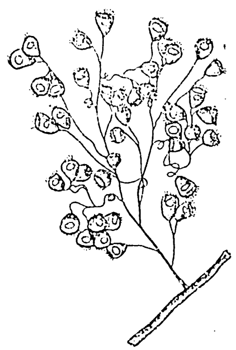

Fig. 8.—A Colony of *Carchesium spectabile*. × 30.

In none of these colonies is the union of the individuals of the colony very vital, but we can readily imagine the separate cells becoming more and more closely united, and the division of labour amongst them becoming more complete, until the individual cells are no longer capable of life separated from the rest. The colony of more or less independent individuals would then have given place gradually to a single multicellular organism, in which the individualism of the separate cells has been subordinated to the life of the whole, thus rendering possible the higher type of the multicellular organism, such as we see exemplified in the freshwater Hydra, described in the next chapter.

Classification of the Protozoa mentioned in Chapter I.

All these unicellular forms, whether they live isolated or in colonies, are included in the lowest phylum of the animal kingdom, the Protozoa. They are all clearly marked off from other animals by their unicellular structure. The group is a very large and varied one, and it is therefore divided into several

[1] For further details see T. J. Parker's *Elementary Biology*, Lesson xii.

classes for convenience in studying, and these classes are again subdivided into sub-classes or *orders*. The forms mentioned in this chapter belong to four different orders.

Order 1. Lobosa. Amongst the Protozoa all those with blunt finger-like processes of protoplasm, like the pseudopodia of Amœba, are included in the order *Lobosa*.

Order 2. Foraminifera. Those similar to the organisms described on page 10 whose shells form chalk rock are known as the *Foraminifera*, for in them the protoplasm is enclosed in a calcareous shell, having in it a special *foramen* or aperture, through which the protoplasm can emerge. There may be one main aperture only, or there may be many smaller ones as well, and so we subdivide the order Foraminifera into the *Imperforata*—those with one main aperture but no small perforations—and the *Perforata*—those with many perforations besides the main aperture.

Order 3. Ciliata. Those Protozoa which have no shell, but in which the outer part of the protoplasm is rather denser than the inner, so forming a cortex (see Vorticella, p. 14), and which have also a band or uniform covering of cilia, are known as the *Ciliata*. This order contains many most beautiful forms, common in pond water.

Order 4. Flagellata. Finally, those which are like the Ciliata in the absence of a shell and presence of a firm cortex of protoplasm, but which have only one, or a few, large vibratile protoplasmic threads instead of many small cilia, are known as the *Flagellata*.[1]

TABLE OF CLASSIFICATION OF GENERA MENTIONED IN CHAPTER I.

Phylum—PROTOZOA.

Order I. LOBOSA. Genus—*Amœba*.
Order II. FORAMINIFERA.
Sub-order 1. **Imperforata**. Genus—*Miliolina*.
Sub-order 2. **Perforata**. Genera { *Textularia*. *Nodosaria*. *Lagena*. *Globigerina*. *Calcarina*. *Pulvinulina*.

[1] There are several other orders which are not mentioned here; for an account of these, and for pictures illustrating the large variety of forms amongst the Protozoa, see the article "Protozoa" by Professor Ray Lankester in the *Encyclopædia Britannica*.

Order III. CILIATA.

Sub-order 1. **Peritricha.** (those with a single band of cilia). Genera *Vorticella.* *Carchesium.* *Zoothamnium.*

Sub-order 2. **Holotricha.** (those wholly covered with cilia). Genus—*Paramoecium.*

Order IV. FLAGELLATA. Genus—*Bodo* or *Heteromita.*

Differences between Unicellular Animals and Plants.

It is often most difficult to draw a line between unicellular animal forms and unicellular plants, for amongst them we find the most primitive forms of each kingdom—the forms which we look upon as most closely allied to the common ancestor from which we suppose both animal and vegetable kingdoms to have arisen, along diverging lines of development. We should expect, therefore, as we approach the lower forms, to find those distinctions which are well marked in the higher organisms becoming less and less well defined, until we get forms of such mixed characters that we cannot say definitely that one is a plant and one is an animal. In spite of this, however, we do find that there are certain characteristics which as a rule distinguish unicellular animals from unicellular plants, the chief of these being the different modes of nutrition of the two classes.

Animal Nutrition.

Typical animals are dependent for their food upon the organic substances formed by other animals or plants, and they take in this food usually in the solid form, the albumens and fats of which it is largely composed not being soluble in water, and digest it within their bodies by the action of a digestive juice secreted by the protoplasm; hence animals need some special method of grasping and "swallowing" such solid food. If the protoplasm is not readily penetrable at any point, the cells must develop a special "mouth" and "gullet," down which the food can be passed into the centre of the protoplasm, as in Vorticella; and cilia or flagella or pseudopodia must be brought into play to bring the food into the "mouth." This mode of nutrition found amongst animal cells is termed *holozoic.*

Plant Nutrition. Typical plant-cells, on the other hand, can absorb the greater part of their food only when it is in the state of solution, but they are able to make use of simple mineral salts and of gases which animals cannot use for food. They absorb through their surface the simpler nitrates and other mineral salts dissolved in the water, but they obtain the carbon they need from the carbon dioxide in the air or dissolved in the water surrounding them. Within the plant-body the carbon is separated and caused to combine with the elements in the dissolved food which has been absorbed. Plants are only able to perform this process of obtaining and assimilating carbon from the air by virtue of the green pigment *chlorophyll*, which is characteristically, though not invariably, present in them and absent in animals. Such nutrition, dependent on the presence of chlorophyll, is termed *holophytic*.

Further, owing to the nature of the plant food and to its presence throughout the plant environment, it can be absorbed by the process of diffusion, through the whole surface of the unicellular organism, and there is no need for any special organs for obtaining food, or for any mouth or gullet to convey the food to the centre of the protoplasmic body; hence the surface of the unicellular plant is usually more regular in outline and is completely surrounded by a permeable cell wall of the substance *cellulose*, which is secreted by the protoplasm. Such a cell wall is found in very few animal cells, the outer protective coat, when present in animal organisms, being formed generally of calcium carbonate (chalk), or of silica, or of a chitinous (horny) substance.

Power of Locomotion is possessed by unicellular plants and animals alike, so that—although the presence or absence of this is a striking difference between the higher plants and higher animals, it cannot be looked upon as a distinguishing characteristic in the lowest forms. Again, a contractile vacuole is more usual in unicellular animals than in plants.

Practical Work on Protozoa

1. Mount a drop of water containing *Amœbae*[1] on a slide and cover with a cover-slip. Examine under the low power of a microscope (Zeiss A gives a convenient magnification). From amongst the debris in the water an Amœba may in time be seen emerging. Watch its movements, and draw it at intervals, showing a few of the various shapes it assumes. Examine under a high power, and find the nucleus, contractile vacuole, and food vacuoles. If possible, watch an Amœba catching its food. Look for stages in division. See it contract as it touches any object.

2. Examine a prepared slide of *Foraminifera* in which there are unbroken shells;[2] also mount a little of the dust rubbed from a piece of chalk rock and examine the broken fragments of shells in it. Sketch from the prepared slide a few typical shells, naming them, if possible, by reference to the article "Protozoa" in the *Encyclopædia Britannica*, or some other book, such as *The Foraminifera*, by F. Chapman.

3. Mount a drop of water in which a few decaying flower-stems have been left for a week, search for the rapidly moving *Paramoecium*. If these organisms are present, put a few shreds of cotton-wool across the water to check their movements, cover with a cover-slip and examine carefully, identifying the structures shown in Fig. 3, *B*.

4. Examine water-weeds from a pond; some may seem to have a delicate white fur on stem or leaf; this very probably may be due to the presence of many *Vorticellae*[1] or other, allied, organisms. Study all you can find, making sketches and notes. Identify where you can by the aid of the aritcle "Protozoa" referred to above.

[1] These can be obtained in 1s. 6d. tubes, plus postage, from Mr. H. Jessop, 30 Becmede Avenue, Kenton, Middlesex.

[2] May be obtained from W. Watson & Sons, 313 High Holborn, London, or from Messrs. Flatters, Milborne & Co., 16 Church Road, Longsight, Manchester, or from any other dealer in microscope accessories.

CHAPTER II

PHYLUM II.: COELENTERATA

THIS phylum includes all those multicellular animals in which the cells are massed closely together, side by side, to form a two-layered body-wall, enclosing a sac-like cavity with a single terminal aperture. The body is radially symmetrical, and definite organs and tissues are developed. Because of the stinging hairs which nearly all these forms can eject, they are popularly known as *stinging animals*, or *Lasso-throwers.* Here are included the freshwater polyps, the marine seaweed-like zoophytes, jelly-fishes, comb-jellies, sea anemones and corals.[1]

Class I.: HYDROZOA

Type: The Hydra or Freshwater Polyp.

This form, like most of those studied in the last chapter, is commonly found in pond water, but it is easily to be seen with the naked eye, for the body in some species, when stretched out to its full length, is frequently as much as $\frac{1}{4}$ of an inch long.

General Form. The thread-like tubular body is usually attached by its lower closed end to some object in the water, a water-weed or piece of stick; the free end narrows slightly, but is open, forming a definite mouth. At a short distance below the mouth there springs from the body a circle of six to eight arms or *tentacles*, which are hollow like the body, their cavities being merely continuations of that of the body. The whole body is very sensitive to touch, changing its shape very rapidly, so that from a long thread-like form with extended tentacles (Fig. 9, *A*) it quickly contracts into

[1] For scientific classification see pages 51 and 52.

a little rounded mass, with mere knobs to represent the tentacles (Fig. 9, *B*).

Different Species. The colour of the body varies in the different species; *Hydra viridis* is bright green, *H. fusca* a brownish colour, and *H. vulgaris* a lighter yellowish-brown. The two last species are also larger, and have usually six relatively long tentacles, reaching in *H. fusca* to several times the length of the body, whilst in *H. viridis* the usual eight tentacles, even when fully extended, are not as a rule as long as the body.

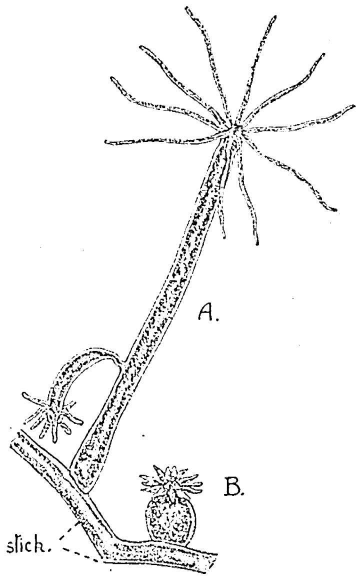

FIG. 9.—*Hydra viridis* (×10) attached to a stick.

A, A fully-extended individual which is budding. *B*, A contracted individual.

Movement. Though usually fixed to one spot, a Hydra can move from place to place, gliding along on the disc at the base of its body, or moving with an action rather like that of a "looper" caterpillar, throwing its body forward and holding firmly to some support with its tentacles, then detaching the basal end and drawing it up close to the mouth and fixing it once more (see Fig. 10). In this way the creature can move along fairly rapidly.

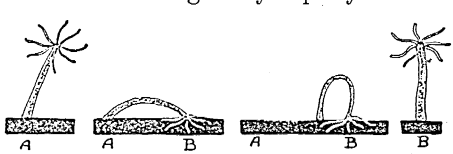

FIG. 10.—*Hydra viridis*, showing successive positions when moving from *A* to *B*.

Food. Hydra feeds on minute water animals and plants which, when touched by the waving tentacles,

are seen to remain adhering to them. The tentacles then contract and bend inwards, carrying the food down to the mouth, whence it is passed into the body-cavity to be digested. The means by which the tentacles hold the prey will appear when their detailed structure is investigated (see p. 27).

Microscopic Structure of the Body-wall. By examining sections of the body or of a tentacle under a microscope it can be seen that the body is multicellular. Every part of the body-wall is built up of two distinct layers of cells, an outer layer of smaller regular cells, which may be distinguished as the *skin cells* (Fig. 11, *B*, *s*), and an inner layer of larger irregular cells lining the body-cavity. These latter, since they alone have to do with the digestion of the food, may be called the *digestive cells* (Fig. 11, *B*, *di*).

Between these two layers of cells is a thin, non-cellular, transparent, gelatinous layer, the *mesogloea*. In *Hydra viridis* the two main layers are apparent even to the naked eye, for the skin cells are colourless, whilst the inner digestive cells are a bright green, so that the cells of the two layers stand out in marked contrast.

The Skin. The skin cells are mainly conical in shape, and are arranged regularly side by side, with much smaller oval cells, the *packing cells*, filling the spaces between their inner narrow ends. The inner ends of all the larger skin cells are prolonged into narrow processes which run just below the skin, parallel to the long axis of the body. These are known as the *muscle processes,* for they have great power of contracting and expanding, and by so doing they cause those remarkable changes of shape in the body of the Hydra which have been noticed. (Compare with the axial muscle-fibre in Vorticella, p. 15.) Each separate skin cell consists merely of a nucleated mass of protoplasm, but, unlike the Amœba cell, each has acquired a definite shape, and its functions are limited. By its sensitiveness to contact each cell acts as an *organ of perception,* giving warning to the organism of the presence of some external stimulus. Then by virtue of their special contractile processes these cells act also as the *organs of motion* of the body. *Respiration* also takes place doubtless over the whole surface of the body. In the processes of nutrition, however, these cells take no part.

From some of the "packing cells" of the skin there develop certain highly specialised cells known as *dart cells* or *thread cells*—also called nematocysts (*nema*, a thread) —which work their way through to the outer surface of an ordinary skin cell (Fig. 11, *B*, *d*), and there perform

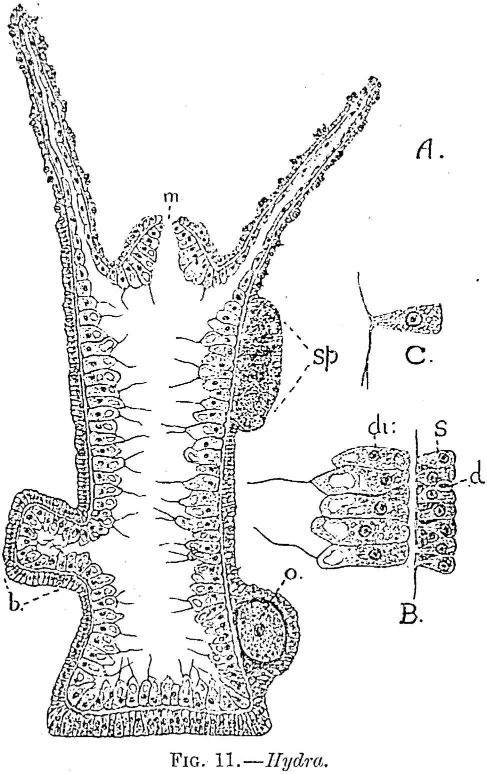

FIG. 11.—*Hydra*.

A, Longitudinal magnified section of the whole body; *m*, mouth; *b*, bud; *sp*, spermary; *o*, egg cell inside ovary. *B*, A few cells of the body-wall enlarged; *s*, skin cells or ectoderm; *d*, dart cell; *di*, digestive cells or endoderm. *C*, One ectoderm cell separated to show muscle processes.

their special function of enabling the Hydra to catch and paralyse its prey.

Dart Cells or Nematocysts. Each dart cell consists of a little oval bag. From the outer side of the bag the wall is extended into its cavity as a hollow finger-like process, ending in

a long, whip-like, spirally-coiled filament, which lies supported in the liquid which fills the bag (Fig. 12, *A*). Surrounding the whole structure, but lying chiefly to one side of it, is the protoplasmic cell from which it has been formed. When the dart cell has reached the surface of the skin there projects from it a tiny protoplasmic thread; this is known as the "trigger hair" (Fig. 12, *A*, *t*), for when it is touched the dart cell immediately "explodes," flinging out the thread as in Fig. 12, *B*. The thread enters the skin of the victim, carrying with it, apparently, some poison, for it has a paralysing effect on such small prey as water-fleas, etc. Some of these dart cells have little recurved barbs at the base of the thread, but these are absent in the smallest darts.

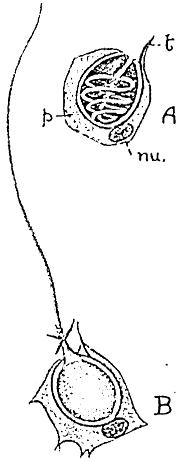

FIG. 12.—*Hydra*, Dart Cells or Nematocysts. *A*, Before using; *p*, protoplasm of cell in which the thread is formed; *t*, "trigger hair"; *nu*, nucleus. *B*, The same cell after the thread has been extruded.

Such specialised structures as these dart cells show a great advance on anything found amongst the simple organisms of the Protozoa.

Nerve Cells. Close to some of these dart cells have been found small, very irregular cells, with large nuclei, resembling the *nerve cells* of higher forms, and it is probable that in Hydra they function as a very rudimentary nervous system.

Digestive Cells. The *digestive cells*, which form the inner layer of the body-wall, are less specialised, though they are considerably larger than the skin cells; in some ways they resemble the primitive amœbiform cell. They lie closely packed, side by side, except for their inner ends, which project freely into the body-cavity and are very irregular in shape, some ending in blunt processes and others in whip-like threads, which may at any moment be withdrawn and a blunt process projected instead. These cells have, therefore, to some extent, a power of individual movement comparable to the movement of some Protozoa.

Digestion may take place in two ways. Some of the digestive cells seem to be specially glandular, and they secrete

into the digestive cavity a fluid which partially dissolves and digests the soft parts of the food, which is then absorbed in the liquid state by the adjacent cells.

Then also the minute solid particles of food may be directly engulfed by the blunt processes of the cells, just as in Amœba, and in this case the digestion takes place *within* the cells. Undigested matter is driven out of the body through the mouth, in the current kept up in the liquid that fills the body-cavity, by the lashing of the whip-like processes of some of the digestive cells.

In the green and brown Hydrae the digestive cells contain the special pigment corpuscles which colour the body.

Pigment. In the case of *H. viridis* the green colouring matter is chlorophyll, the same pigment that is found in plants; and by virtue of its presence the Hydra, though an animal, can to some extent feed holophytically, obtaining the carbon they need from the carbon dioxide dissolved in the water in which they live (see p. 21).

Interesting investigations have been made into the nature of these green corpuscles, and it has been shown that they are really independent, unicellular plant-organisms of the genus *Zoochlorella,* which are living inside the body of the Hydra. Their presence is to the mutual advantage of both plant and animal, for whilst the plants aid in the nutrition of the animal, they gain in return a safe shelter, where they have no lack of water containing carbonic acid and dissolved food matter. Such a union of distinct organisms for their mutual benefit is known as *symbiosis.*[1]

Reproduction by Budding. Sometimes, especially when food is plentiful and growth rapid, a Hydra multiplies by the very simple method of *budding.* A small lump appears at some point in the side of the body, and this grows outwards. When examined, it is found to be formed of a lateral extension of the body-cavity, which pushes the double body-wall in front of it, the cells rapidly dividing to keep pace with the growth (Fig. 11, *A, b*). The outgrowth narrows at its free end, a mouth appears, and round this a ring of hollow tentacles develops, so that in time the bud takes on

[1] *Zoochlorella* enters into a similar partnership with green, freshwater sponges. See p. 59, and Gamble and Keeble, *Q.J.M.S.* xlviii., 1904, p. 363.

the form of the parent to which it is still attached (see Fig. 9, *A*). Sooner or later it becomes constricted at the base, and then entirely separated; and in this simple way a new individual is formed, and enters upon a separate existence.

This method of reproduction might be compared to the growth of a new plant by means of a runner growing out of the parent-plant; but just as in the higher plants there is normally another method of reproduction, which depends upon the fusion of two special cells—the *sperm* or *generative cell* from the pollen grain, and the *egg cell* in the ovule within the ovary—so here we find another method of reproduction, in which, similarly, an egg cell is formed inside an ovary and is fertilised by a sperm cell.

In both cases the fusion of the sperm with the egg cell is known as *Fertilisation*, and the result is to stimulate the egg cell to further growth and division. In the plant this results in the formation first of the seed, and then from the seed of the new, young plant. In the animal the fertilised egg develops directly into the new individual, without a "seed" stage intervening. In the Hydra the structures are all much simpler than in the higher plants and animals.

Sexual Reproduction. When this method of reproduction is about to take place, little swellings are to be seen on the surface of the body of the Hydra (Fig. 11). Each of these swellings consists merely of an up-pushing of the superficial skin cells, due to the rapid multiplication of the "packing cells" at one spot. The swellings nearer the base of the body become larger than the others; these are the *ovaries*, and inside each, one cell enlarges at the expense of the others, engulfing and digesting its companion cells, much as an Amœba engulfs and digests its food; finally, the single large cell which remains draws in its irregular processes, and after certain nuclear changes it becomes the ripe *egg cell* or *ovum*, ready for fertilisation, without which stimulus it can now develop no further.

Meanwhile the smaller swellings nearer the upper end of the Hydra have become *spermaries*, for in these each of the "packing cells" becomes a minute *sperm cell*, not more than $\frac{1}{500}$ of an inch in length.

These sperm cells are in appearance very unlike the round passive sperms or "generative cells" found in the pollen-tube

of most higher plants, to which, however, they correspond. Here each consists of a small oval head—formed from the nucleus of the cell—and a vibratile tail of protoplasm. By the vibration of these tails the sperms can move rapidly, and in so doing they break down the spermary wall covering them and swim out into the water, making their way to an ovary. Many of them may approach a single ovary, but only one of them makes its way through the now ruptured ovary wall into the egg cell, fusing with it, and so accomplishing the act of fertilisation.

The fertilised egg has now the power of dividing, and it does so rapidly, the cells formed all remaining in close contact, in a little solid mass of cells, which is the little embryo Hydra. This secretes round itself a chitinous membrane, falls to the bottom of the water, rests for a time, and then continues its development into a new Hydra like its parent.

This method of reproduction may be taken as being in essential points similar to that which obtains in all the higher animals, though it is only in some of the lower forms that we find both ovaries and spermaries functional in the same individual. When this is the case the animal is said to be *hermaphrodite*,[1] a term which is also used to describe a flower containing both ovary and stamens.

In comparing this method of sexual reproduction with that in Vorticella (pp. 16-17), it is clear that the sperm cell may be compared to the microgamete and the egg cell to the macrogamete; but whilst in Vorticella the two gametes are essentially separate complete individuals—one of the two at any rate being capable of further independent life even if fusion does not occur—in Hydra the gametes are merely special cells differentiated in the body, which are incapable of further development unless stimulated by fusion, and which, after such fusion, develop into a new individual completely independent of the parent form.

Regeneration. Although the multicellular Hydra is one single organism, all the cells with their different functions together completing the individual, yet its structure is very simple compared with that of the higher animals, and the differentiation of the parts of the body is not very deep-seated. This is demonstrated by the fact that the organism possesses

[1] From the names of the Greek god and goddess, Hermes and Aphrodite.

to a remarkable degree the power of regeneration of lost parts. If it is cut in two transversely, the bottom half will form a new mouth and tentacles, whilst the top half will form a new base; in fact, even quite small pieces of the body are said to be capable of reproducing the whole.

Specialisation of Cells. In such a form as Hydra the specialisation of cells into separate tissues is most striking. The differentiation of skin cells, digestive cells, dart cells, muscle processes, nerve cells, eggs and sperms, all mark the much higher stage of evolution of this form, as compared with even the most complex of the Protozoa. On the other hand, the form of the egg cell and its behaviour as it matures strikingly recall the Amœba. The digestive cells also, with their power of throwing out irregular processes to engulf food, or whip-like processes for lashing the water, resemble many Protozoa, and indicate the primitive nature of these simple multicellular forms and their close affinity with the Protozoan organisms from amongst which they must have taken their origin.

Colonial Hydra-like Forms, or Hydroid Zoophytes.

There are many genera which—though they begin life as a single individual or "polyp" very similar to Hydra—produce, by lateral budding, a large colony all united by a common branched stem which is permanently attached to one spot.

Many of these colonial forms also secrete round their common stem a horny, tubular, protective covering, which may stop at the bases of the separate polyps, or may form cups extending right to the bases of the tentacles, so that each polyp can be completely withdrawn into its cup.

Colonial Forms with horny Cups. The yellow, sandy-looking *Sea Firs* which are frequently picked up on the shores of our rocky coasts after stormy weather, and are commonly mistaken for seaweeds, are examples of such colonial hydroids in which horny protective cups are present. In one genus, *Sertularia*, the polyps are set on each side of the axis (Fig. 13), which may be much branched and arises from a creeping stolon attached to a rock or shell. *Sertularia argentea* is the beautiful Squirrel Tail zoophyte. In *Antennularia* and *Plumularia* the polyps grow from one side of the stem

only. *Obelia* forms a light fur-like growth on the wooden piles of piers and wharfs.[1]

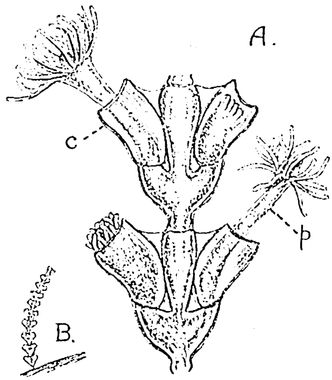

FIG. 13.—*Sertularia pumila.*
B, Natural size; *A*, enlarged *p*, polyp; *c*, horny cup.

Those with no horny Cup. *Bougainvillea* is a little marine form which is found attached to rocks and shells below the surface in the lowest tide pools, many colonies, each one or two inches long, growing together, and so forming minute, branched, tree-like growths (Fig. 14, *A*). The particular point of interest about this genus is the specialisation of some of the polyps to form bell-shaped individuals which alone form reproductive cells. These peculiarly modified individuals break away from the colony, and swim off like minute jelly-fish, and so serve the purpose of dispersing the genus far and wide.

A reference to Fig. 14, *B* and *C*, will make clear the main characters of the two kinds of individuals. The ordinary nutritive polyp is very like a Hydra with a short tubular body and a ring of tentacles round the mouth cone.

Medusae. The reproductive swimming bells, or *Medusae*, as they are called, are shown in Fig. 14 in different stages. They arise as lateral buds, assume a bell or goblet shape, and develop a mouth-tube, which hangs down inside the "bell."

[1] For full account see *Text Book of Zoology*, by T. J. Parker and W. A. Haswell.

The medusa[1] is transparent and of a jelly-like consistence, owing to the great thickness of the gelatinous layer, known as the *mesogloea*, which lies between the skin and digestive cells. (Compare Hydra, p. 25.)

In the wall of the bell there is at first a continuous cavity, lined with digestive cells; but after a while—by the

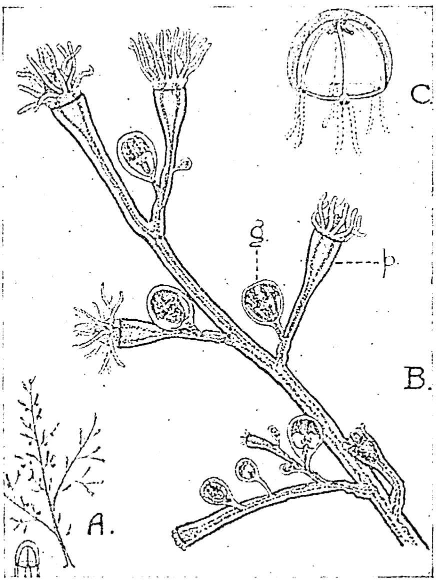

FIG. 14.—Bougainvillea.

A, Colony natural size; *B*, colony enlarged; *C*, single reproductive individual or medusa; *p*, nutritive polyp; *g*, a medusa bud.

closing together of the inner and outer parts of the wall except just at the top and along four radial lines and also along the margin of the bell—the cavity is restricted to a central chamber, communicating with the exterior by the

[1] These medusae can readily be obtained, late in the summer, by drawing a muslin net behind a boat, or even by skimming the surface of a rock pool with a net, and then dipping the net into a pail of sea-water. They are so small and so transparent that they may be overlooked at first. They vary in size from a mere speck to a ball half an inch in diameter.

mouth-tube, and extended in the form of four radial canals, which run into a circular canal round the margin of the bell (Fig. 15).

The concave under-surface of the bell is partially closed by a skin-like ledge, or *velum*, which grows inwards from its margin.

From this margin also, just below each of the four radial canals, hangs down a pair of solid tentacles. At the base of each of these is a little mass of pigment, to which perhaps is due a certain sensitiveness to light possessed by these medusae; hence these pigment masses are termed "eye-spots."

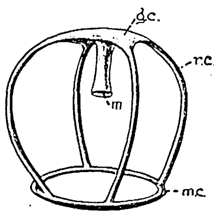

FIG. 15.—Diagrammatic representation of the Canal system of the Medusa of Bougainvillea.

m, Mouth; *gc*, gastric cavity; *rc*, radial canal; *mc*, marginal canal.

Each medusa swims like a jelly-fish by alternately contracting and expanding its bell, and so forcing water out and in. This movement is brought about by muscle processes of the skin cells, such as those in Hydra, and also by special *muscle fibres*—long nucleated contractile cells quite separate from the skin cells; in fact, in these medusae there is, in some parts of the body, a layer of these muscle fibre cells, between the skin and digestive layers, as well as the much thicker layer of non-cellular jelly or mesogloea.

The *nervous system* is also more highly developed, for there is a double ring of nerve cells with fibre-like processes round the margin of the bell, as well as an irregular network of the same just below the skin cells on the inner surface of the bell.

This greater differentiation of the muscular and nervous systems is doubtless due to the more varied needs of the freer, more independent life of the medusa, compared with that of the more or less stationary Hydroids. The medusa swims away to fresh regions, and must be more active and "alive," to face successfully the new, varying conditions of life.

The *reproductive cells* are produced usually in the skin cells of the mouth-tube, along four radial lines corresponding to the radial canals. The sperm cells are formed on one medusa and the egg cells on another.

Egg Development. Each fertilised egg cell develops into a little elongated mass of cells, which becomes covered with cilia. In this stage it escapes from the medusa, and swims slowly through the water. Finally it settles down in an upright position on some rock or shell, loses its cilia, and grows into a hydriform body, which soon buds freely and forms a new hydroid colony of *Bougainvillea.*

Modifications of Medusae. The formation of medusae in this way, by *lateral budding* from a hydroid colony, is only found in the class Hydrozoa; and the medusae, if they develop fully, are always of the type described above, having a velum, radially placed ovaries and spermaries, and a continuous marginal nerve ring. In many of the Hydrozoa, however, the reproductive individuals do not ever become free from the colony, but remain attached to it in a rudimentary condition, sometimes being nothing more than a sac-like body enclosing eggs or sperms, as is the case in the freshwater form *Cordylophora,* which occurs attached to the underside of floating wood in fresh or brackish water.

Hydra itself is included amongst the Hydrozoa, though in it the eggs and sperms are borne direct on the body of the ordinary nutritive polyp (see page 29).

Practical Work on Hydrozoa

Obtain some *Hydra viridis* from a pond, or, if this is impossible, from a dealer.

Mount, in a drop of water on a slide, a small piece of weed with a Hydra attached to it; if the Hydra is detached it can be taken up with a dipping tube and placed on the slide; a small piece of stick or weed should be put in the water before the cover-slip is put on, otherwise this may crush the body of the Hydra undesirably. Examine under the low power of the microscope, watching the body expand; when it is fully extended verify the different facts stated in the text. Look for specimens that are budding or reproducing sexually. Sketch in different stages.

Prepared sections of the body should be obtained and examined under the microscope if possible, so that the different tissues may be studied in detail.

Put several Hydrae into a small glass vessel partly filled with pond water or clean rain water, and supplied with fresh duck-weed and other water-weed from a pond; cover the vessel and

keep in a light but not a sunny place; watch the life of the Hydrae and the formation of new individuals by budding.

Obtain other species of Hydra and watch them also.

Examine any colonial Hydroids and medusae that you can obtain,[1] sketching them carefully and identifying them if possible by reference to such a book as *British Hydroid Zoophytes*, by T. Hincks (2 vols., 1868).

The Plymouth Aquarium Guide Book (price 1s.) is a most useful guide for beginners in identifying common hydroids, as well as for its interesting notes on all the common marine fauna of the Devonshire coast.

[1] If it is not possible for the student to get these direct from the sea, they can always be obtained from the Marine Biological Laboratory, Plymouth.

CHAPTER III

COELENTERATA (*continued*)

Class II. : SCYPHOZOA (Jelly-fishes)

Type: **The Common Jelly-fish** (*Aurelia aurita*).

The ordinary large *Jelly-fishes* are very like the medusae of the Hydrozoa, but they develop differently and have a somewhat different structure.

The commonest form round our coasts is *Aurelia aurita.*

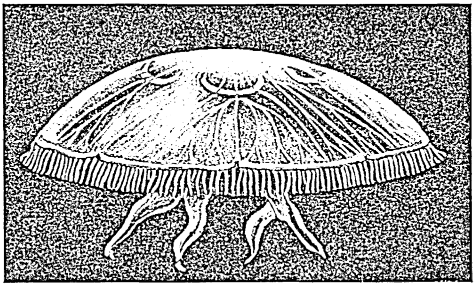

Fig. 16.—The Common Blue Jelly-fish (*Aurelia aurita*).
Seen from the side, with the mouth-lobes hanging down below, and the horseshoe-shaped reproductive organs showing through the transparent upper surface.

These jelly-fishes are often washed up in large numbers on flat beaches, and vary in size from two inches to a foot or more in diameter.

Aurelia has an inverted, milky-blue, bowl-shaped body with eight notches round the margin of the bowl, and a fringe of small marginal tentacles (Fig. 16); also at each notch is a

pair of very small finger-like processes known as the "marginal lappets."

The mouth-tube is very short and can only be seen by looking under the bell, but at each corner of the mouth a long "mouth-lobe" hangs down (Fig. 16). In a large individual these mouth-lobes may be several inches long; they are delicate membranous structures, frilled at the edges and well supplied with stinging thread cells, which render an encounter with a jelly-fish unpleasant to the sea-bather, and from which it

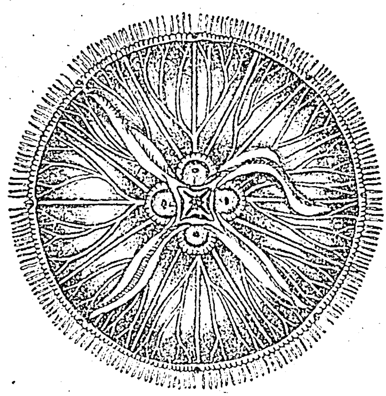

FIG. 17.—*Aurelia aurita*, viewed from below.

acquires the name of the "sea-nettle," though this special species is harmless compared with the less common *Pelagia*, the sting of which is decidedly unpleasant; the mouth-lobes of this latter genus may be a foot or more in length, and its eight marginal tentacles are as long as the mouth-lobes. If the jelly-fish is viewed from below (Fig. 17), the mouth and mouth-lobes and radial canals are well seen, and also the four brightly-coloured, horseshoe-shaped or circular reproductive organs which contain either the egg cells or the sperms. These are formed from the cells lining the digestive cavity, but they show clearly through the transparent wall. They are at first horseshoe-shaped, but each may ultimately form almost a complete ring. Just below each of them is a

pit in the under surface of the bell, communicating with the exterior by a small aperture, the sub-genital aperture; water passes freely in and out of each of these, and this may be of value in renewing the air supply, for the water in the pit is only separated from the genital organs by a delicate thin layer of cells. Lying inside the digestive cavity, close to the reproductive organs, there are many little ciliated filaments, the gastric filaments, richly beset with stinging cells, the function of which is to paralyse any prey that may be swallowed alive. These do not occur in any of the Hydromedusae described in Chapter II.

The *nervous system* also differs from that of the medusae of the Hydrozoa, for instead of a ring of nerve cells there are eight groups of such cells near the eight pairs of marginal lappets where special sense organs are situated; these latter consist merely of little pigment masses or eye-spots, and also of small pits, lined with sensory cells, known as *olfactory pits*, by means of which the animal may detect the presence in the water of things good to eat or the reverse; little, however, is known of the special functions of these structures. They are often called "tentaculocysts," for they are thought to represent modified tentacles; they only occur in these large jelly-fish, and form one of the distinguishing marks between them and the medusae of the Hydrozoa, from which they also differ in having no *velum* to the bell.

Development. In the Hydrozoa the medusa is merely a specially modified individual, formed by budding on a colony of ordinary hydroid polyps, but in the Scyphozoa the medusa is the dominant phase, the hydroid when present being a little insignificant structure, about half an inch long, known as the *Scyphistoma*.

This little hydroid develops in the late summer directly from the fertilised egg. Even before leaving the parent jelly-fish, the egg has developed into a little oval hollow sac open at one end, with a two-layered wall covered with cilia, by means of which it makes its way out of the mouth of the jelly-fish into the water. It swims freely for a short time (being known in this stage as the "planula"), but finally it becomes attached to some object in the water, loses its cilia and develops a mouth as shown in Fig. 18, *B* and *C*. Tentacles then begin to grow out round the mouth until there are sixteen arranged

at regular intervals, the mouth-cone is pushed outwards and becomes quadrangular, and four folds of tissue grow inwards from the body-wall, forming the four "gastric ridges" which alternate in position with the angles of the mouth. From these gastric ridges arise the sexual organs and gastric filaments described previously.

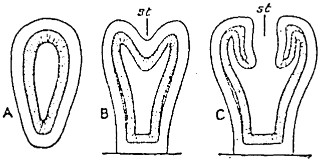

FIG. 18.—*Aurelia aurita.* Stages in the development of the hydroid. (After Korschelt and Heider.)
st, Mouth and mouth-tube developing.

Above each gastric ridge the surface of the mouth-cone becomes pushed in to form a narrow funnel-shaped pit. The final result is the formation of a little polyp, not very unlike a small Hydra; this polyp is the *Scyphistoma* (Fig. 19, *A*). In the autumn each such Scyphistoma gives rise, by a curious process of repeated transverse constriction, to a whole series of little embryo jelly-fishes, each of which is known at first as an *Ephyra.* First there appears in the hydroid body below its tentacles a series of ring-like constrictions which deepen until the polyp begins to look like a pile of very deep minute saucers, the margin of each saucer becoming deeply eight-lobed (see Fig. 19, *B*). This stage is known as the *Strobila.* After a time the constriction reaches right across the polyp, and the saucer-like segments, one after the other, gradually separate from the polyp, turn upside down, and swim off as tiny shallow jelly-fishes or *Ephyrae.* As the constriction has proceeded, a portion of the gastric cavity with the gastric ridges has been nipped off in each Ephyra. This cavity is closed below when the constriction is completed, but on the side which is uppermost before it is set free, it is drawn out into a little mouth-tube, ending in an open mouth. This mouth-tube can be seen through the side of the transparent Ephyra in Fig. 19, *C.* The curve of the surface is at first very slight, but rapidly increases; the portions between the lobes grow out so that the margin becomes circular, the marginal tentacles develop, the gastric canals form, and the mouth-lobes protrude; thus the Ephyra gradually assumes the adult form shown in Fig. 16. The medusae of some jelly-fish develop straight from the egg without this complicated process of the transverse fission of a hydroid; this is

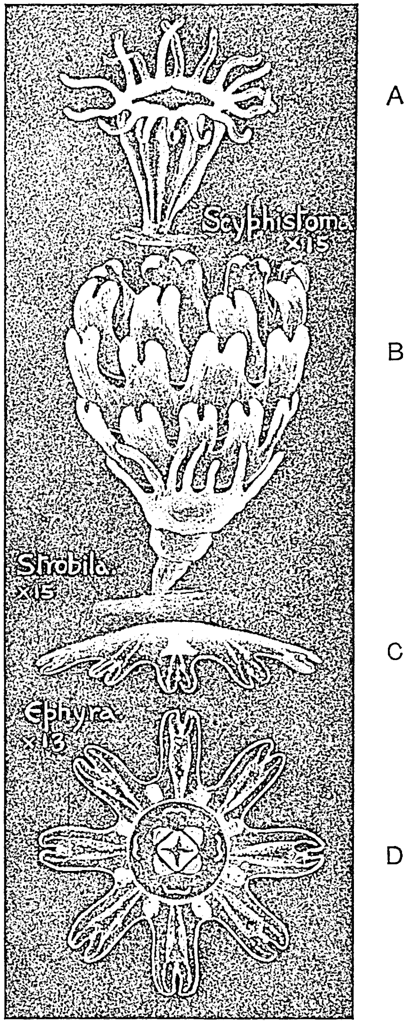

FIG. 19.—*Aurelia aurita* developing Medusae.

A, Scyphistoma before transverse fission. *B*, Scyphistoma undergoing fission. Several Ephyrae have already floated off. Below the last Ephyra which is to be set free, the Scyphistoma is developing the tentacles characteristic of the Hydroid. (It is unusual for constrictions to appear below these as were seen in this specimen.) *C*, One Ephyra, side view. *D*, One Ephyra seen from below.

Pelagia. so in the common *Pelagia*, and this may be one reason for the wide distribution of this genus in the high seas, for it is not dependent on the shallow waters of the shore, where a suitable place of attachment might be found for a fixed Scyphistoma stage. One species, *Pelagia phosphora*, occurs in the Atlantic and Indian Oceans, and a number of

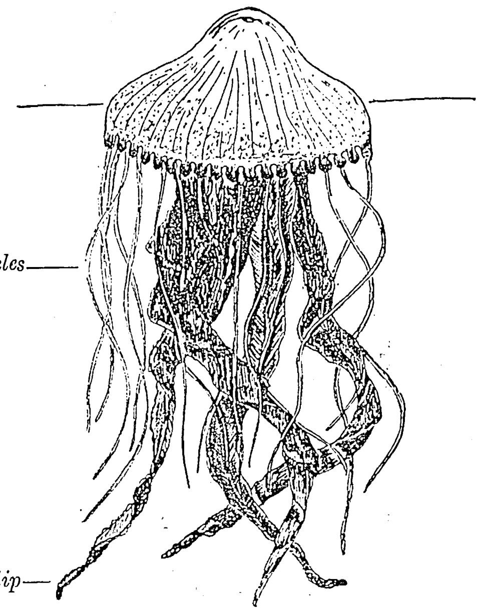

FIG. 20.—Chrysaora (× ⅓). (Sherriffs.)
Lip or oral lobe.

these beautifully phosphorescent forms may cause a line of light many miles in length on the surface of the sea.

The genus *Chrysaora* is also found occasionally on our coasts. It may be distinguished by its many long marginal tentacles and long oral lobes with well-developed stinging cells.

Another jelly-fish found on the western coast of Ireland and Scotland is *Rhizostoma pulmo*, which has an umbrella-shaped body two feet in diameter, sometimes green in colour with a red margin and with long bright blue oral lobes but no

marginal tentacles; occasionally this form drifts into the English Channel.

Class III.: CTENOPHORA

General Formation. Sometimes there may be seen floating in the sea in the company of ordinary jelly-fish, and looking rather like them, the little *Comb-jellies* or *Sea-gooseberries.* They resemble their large companions, however, chiefly in their jelly-like consistency; in detail they differ so greatly in structure that some zoologists class them in a separate phylum, the Ctenophora, but more usually they are included amongst the Coelenterata, although they do not possess the characteristic nematocysts of this phylum. A common Mediterranean species, *Hormiphora plumosa,* is shown in Fig. 21.

British Sea-gooseberry. The commonest British form is *Pleurobrachia pileus*; these creatures occur in shoals in the early part of the summer, though they separate later. *Pleurobrachia* is very like *Hormiphora.*

Each individual has a pear-shaped body, $\frac{1}{4}$ to $\frac{3}{4}$ inch long, made of transparent jelly and with the mouth at the lower, narrower end.

Sense Organ. Lying in a slight depression at the opposite, broader end is a special, rather elaborate sense organ; this appears as if it must be an organ for maintaining equilibrium, for there is in the central shallow depression a little mass of calcareous particles supported on stiff but flexible cilia. A slight lurch of the body to one side or the other will cause a slight displacement of this mass, and a stimulus is then carried from the affected cilia along certain special lines of other cilia to the swimming organs of the creature and the balance is readjusted.

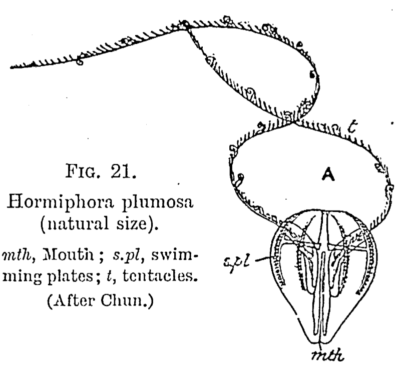

FIG. 21.
Hormiphora plumosa (natural size).
mth, Mouth; *s.pl*, swimming plates; *t*, tentacles.
(After Chun.)

The Swimming Organs. The swimming organs of all Ctenophora are quite unique, and give to them the popular name of "Comb-jellies." They consist of eight bands of comb-like plates which run from the area round the sense organ down eight radial bands towards the mouth, stopping about two-thirds of the way down (see Fig. 21, *s.pl*). These plates are in constant motion, the cilia at their free margins lashing up and down. The plates move in succession with a wave-like rhythm, catching and reflecting the light as they do so, often causing a beautiful rainbow coloration.

Tentacles. *Pleurobrachia* also possesses two long, delicate solid tentacles which float out behind it as it moves, but which can be withdrawn into two pit-like sheaths which lie one on either side of the body. These tentacles are covered by peculiar "adhesive cells" or "glue cells"; these secrete a substance which causes them to stick to any body they touch, and so assist in the capture of prey. It should be noted that they are not homologous with the nematocysts of Hydra.

Beroë. The genus *Beroë* is also found off our coasts. *Beroë cucumis* has a body sometimes quite $3\frac{1}{2}$ inches long; it has no tentacles, and the mouth is very wide so that the body is somewhat thimble-shaped; it moves rapidly, and devours other Ctenophora and even small fishes.

Venus' Girdle. *Cestus Veneris*, the Venus' Girdle, is found in the Mediterranean and in the Atlantic Ocean, but its beautiful, transparent, ribbon-like form is not to be seen off British coasts.

PRACTICAL WORK ON THE JELLY-FISH (*Aurelia*)

1. These animals should be studied alive in their natural habitat, since after death their soft bodies lose their beauty of form and colour, and change their shape very greatly.

The best way of getting them is to lift them out of the sea beyond low-tide mark in a pail of water, and then to transfer them to a large tank of sea-water, or a clear rock pool, dipping the pail right in, so that they gradually float out; in this way beautiful undamaged specimens of *Aurelia* may be obtained.[1]

2. Further examination of dead pickled specimens [1] is desir-

[1] These are also supplied by the Marine Biological Laboratory, Plymouth.

able, and one should be cut in halves longitudinally to expose the gastric cavity and the structures within it.

Class IV.: ANTHOZOA or ACTINOZOA

(Sea-anemones and Corals)

Type: The Sea-anemone.

There are a great many different genera of Sea-anemones common round our coasts, where they are to be seen fixed to the rocks between high- and low-tide marks; they vary considerably in external form and in their beautiful colours, but all have essentially the same general type of structure and of life-history.

External Appearance and Habits. The body consists of an almost cylindrical column, varying in length from a fraction of an inch to 6 or 7 inches; it broadens slightly at the base, and this end is attached to a rock, whilst the narrower upper end consists of a flat disc with a slit-like mouth in the centre, and a fringe of tentacles (usually some multiple of six in number) all round the margin of the disc.

If touched, the whole body seems to collapse, for the water which filled its cavity is expelled, and it immediately becomes an almost shapeless mass. The tentacles are also tucked away quite out of sight, for a circular muscle round the top of the body contracts, and pulls together the margin of the disc, like a string drawn round the mouth of a bag. Both the tentacles and the body-wall are furnished with many stinging cells (nematocysts), which serve to protect the animal from enemies and also aid it in killing its prey, which consists of worms, shrimps, and many small animal forms; these are paralysed by the nematocysts and then passed through the mouth into the digestive cavity within, the indigestible parts being ejected again through the mouth.

Though usually stationary, a Sea-anemone can move slowly over the rocks, gliding along on its broad base. Certain anemones will occasionally detach their bases from the rock, and drag themselves along by their tentacles in an inverted position; this is said to have been observed frequently in the case of anemones kept in aquaria.

Internal Structure. One of the most striking differences in internal structure between the Sea-anemone and the Hydra is the position of the *mouth-tube*. In Hydra this projects outwardly as a short cone; in the Anemone it is

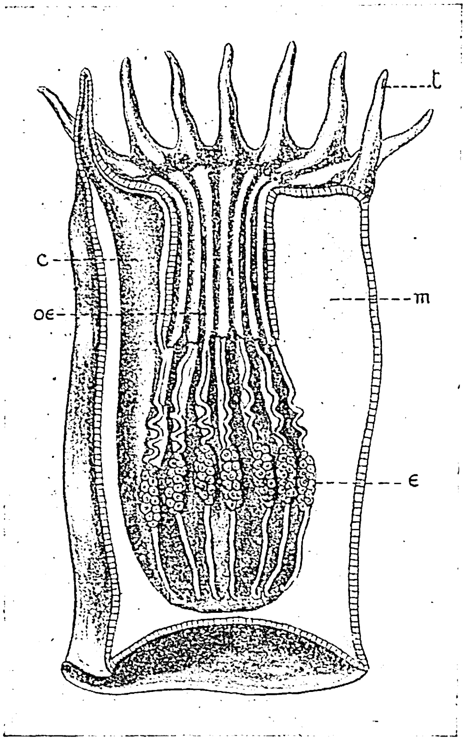

FIG. 22.—One-half of the Body of a Sea-anemone. (Diagrammatic.)

t, Tentacle; *oe*, gullet or oesophagus; *m*, one mesentery or septum seen in surface view; the six others shown are seen from their inner edges; *e*, reproductive cells on the free edge at the base of a septum; *c*, cavity between two septa.

much longer and is turned inward, so that it forms a gullet extending some distance into the body-cavity (Fig. 22).

In the Anemone also, the body-cavity is partially subdivided into radial chambers by a number of pairs of thin membranous partitions or *septa* which grow inwards from the body-wall. These partitions are some multiple of six in

number, and are attached to the base of the oral disc above, to the base of the body-wall below, and by their inner margins to the wall of the gullet, so far as this extends, but from the base of the gullet downwards the edges of the membranes project freely into the body-cavity (see Fig. 22); hence transverse sections taken through the body in the region of the gullet will have the appearance shown in Fig. 23, *A*, whilst those taken at a lower level will be seen as in Fig. 23, *B*.

Not only do all the different chambers of the body-cavity communicate with each other freely below, but each partition is perforated not far from the top by one or more pores;

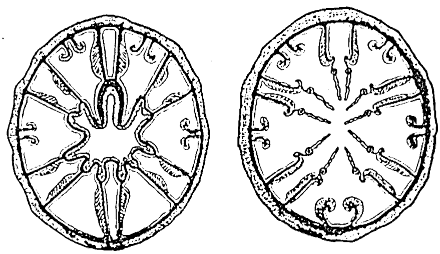

FIG. 23.

A, Transverse section of the body of an Anemone in region of gullet. *B*, Transverse section of the body in region below gullet. (Diagrammatic.)

each chamber is continued into the cavity of the tentacle above it, and so all parts of the body-cavity are in free communication.

Muscles are present on the septa, and the arrangement of these is one of the characteristics used in classifying Anthozoa. It will be seen, by reference to Fig. 23, that the position of the muscles on the two pairs of septa on either side of the plane of symmetry of the body differs from that of the muscles on the other pairs of septa.

Reproduction.

On the free margins of the partition walls gastric filaments are developed, recalling the gastric filaments in a Scyphozoan (see p. 39); these probably secrete a digestive juice; also the generative organs, either *egg cells* or *sperms*, develop on these septa (see Fig. 22, *e*). The sexes are nearly always distinct, though a few rare hermaphrodite anemones are known (*e.g. Cerianthus*).

The fertilised eggs usually undergo a certain amount of development inside the parent anemone, forming a little jelly-like ciliated larva which escapes through the mouth of the parent and lives a free-swimming life for a time, before settling down in one place and assuming the adult form.

Stinging Cells. The stinging cells are abundant on the tentacles and also on the outer surface of the body-wall; in some Sea-anemones they are grouped together in little batteries of cells, which may form conspicuously bright-coloured beads round the margin of the mouth-disc, at the bases of the outer tentacles, as in the Common Beadlet (*Actinia mesembryanthemum*), which is very common on our coasts. This is a form with many tentacles, and with a body very variable in colour, but usually of a deep red, with bright-blue spots round the disc, and a line of bright blue round the base of the column. The dart cells in this species are not sufficiently strong to pierce human skin, but their ejection when touched causes the tentacles to adhere slightly, producing a peculiar, sticky feeling.

In other genera there are special defensive organs in the shape of long threads covered with the stinging dart cells; these threads arise on the internal vertical septa, but they can be projected through holes in the body-wall, and then drawn in again; they are known as *acontia*.

Corals.

Devon Cup Coral. In nearly all our British Anthozoa the polyp consists of a soft or leathery body with no supportive skeleton; but a few, such as the Devon Cup Coral (*Caryophyllia smithii*), form calcareous matter within the body-wall, and the calcareous particles become fused together, attaching the anemone firmly to the rock on which it grows, and making the body-wall hard and strong; vertical calcareous plates are also formed, alternating with the mesenteries or membranous septa described above.

The Cup Coral is to be found in many parts of Devon and Cornwall between high- and low-tide marks, but is more plentiful in deeper water.

From such a form as the Cup Coral it seems natural to pass on directly to the reef-building corals of warmer seas,

the *Madrepores.* In these forms the young polyps bud, and the resulting individuals remain connected together, so that colonies are formed as in the Hydrozoa.

Reef-building Corals or Madrepores.

Each polyp before it buds produces its own stony support, having a form similar to that described in *Caryophyllia*, *i.e.* with a stony base, cup-like wall, and vertical septa. When it buds, this "skeleton" is added to continuously, but the living tissues at the base gradually die, the polyps only inhabitating the ends of the branches. So the colony grows, year after year, continually increasing in size, and in time consisting of thousands of living polyps occupying the ends of branches which have arisen in connection with, and still are attached to, a mass of calcareous matter, representing the supports of the ancestral polyps. Fig. 25 represents a small branch with the cups of about 200 polyps attached to it. In this way immense belts of solid calcareous rock have been constructed by these minute soft-bodied animals, and it is such rock that forms the banks known as coral reefs.

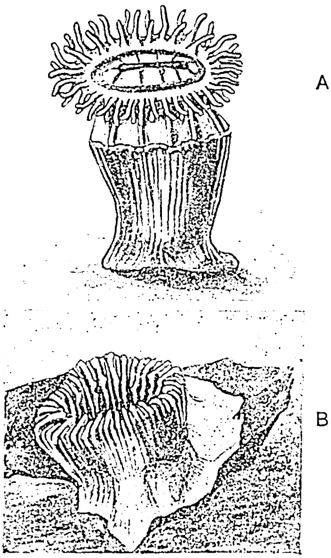

FIG. 24.—The Devon Cup Coral (*Caryophyllia smithii*).

A, Live specimen with polyp intact. *B*, Calcareous skeleton.

These colonial forms flourish best in water not deeper than twenty fathoms and of a temperature not lower than 68° F., and hence they are chiefly found in warm latitudes, and arise fairly close to land where the water is shallow. They are, however, known at greater depths and in colder water.

The fact that coral reefs are found at a great depth was explained by Charles Darwin by the theory that in such cases the coral polyps which originated the reefs started to grow at the sea-bottom, in shallow water near some coast, but that the land and sea-bottom were steadily sinking, and con-

tinued to do so for long ages, but at such a slow rate, that though the bottom of the reef became uninhabitable to the polyps, those above still flourished, multiplied, and spread upwards, and so the reef grew continuously, based on the foundations built by preceding generations; such subsidence of the land would also cause the reef to become more and more widely separated from the coast until many miles of sea might intervene.[1] The most striking example of such a coral reef is the Great Barrier Reef, which runs for 1200 miles parallel to the N.E. coast of Australia, and distant about 80 miles from it, whilst the reef itself is 50 miles in width, a tremendous structure to have been built up by organisms so minute and insignificant individually as these little coral polyps.

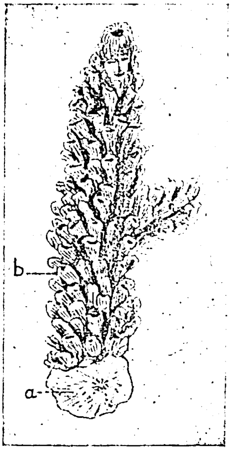

Fig. 25.—A Branch of a Colony of Madrepora.

a, Central axis, the broken end showing the canal up the centre; *b*, cup of one polyp.

Coral reefs often surround or fringe islands in tropical seas. In some cases they have formed a fringing reef right round an island which has subsequently disappeared owing to subsidence, while the coral reef, which continued to grow upwards, was apparently raised again, so that it now projects above the water, and surrounds a shallow salt lake. Such a ring-like coral island is called an *Atoll*.

Coral reefs always tend to spread outwards, away from the land, for the polyps flourish best where they are most exposed to the splash of the waves which bring them air and food.

All the common reef-building corals are similar to Madrepora in having six—or some multiple of six—tentacles, and a skeleton which extends into the body-wall of each polyp.

The Red Coral. The Common Red Coral (*Corallium rubrum*), which is used for ornaments, belongs to a separate division of the Anthozoa, with polyps having eight tentacles

[1] This subsidence theory is now much questioned in some cases; see J. S. Gardiner, *The Fauna and Geography of the Maldive and Laccadive Archipelago*, 1902, vol. i. pt. ii. p. 172.

and mesenteries. The common stem of the colony in this form secretes an internal axial skeleton, which is calcareous, solid, and inflexible, the polyps projecting like buds from the enveloping living cells. This precious coral is obtained chiefly from the Mediterranean Sea, on the floor of which it forms branching masses about one foot high.

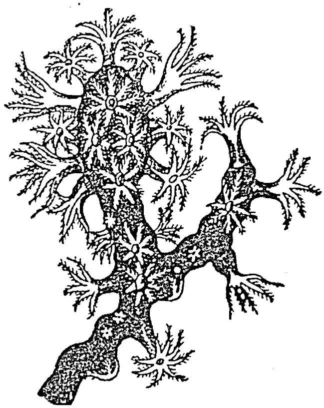

FIG. 26.—*Corallium rubrum.* (After Lacaze-Duthiers.)

Classification of the Coelenterata mentioned in Chapters II. and III.

Class 1. **Hydrozoa.**—Here the dominant phase is a Hydra-like form, either solitary or forming a branched colony. In the colonial forms special individuals are usually modified for reproduction, and in some cases these become transformed into free-swimming medusae; they may, therefore, be said to develop as lateral buds from the colony. The sexual cells are always discharged directly into the surrounding water.

Sub-class A.—*Sea Firs*, Hydroids with horny cups to protect the polyps; *e.g. Sertularia*, *Antennularia*, *Plumularia*, *Obelia*.

Sub-class B.—Hydroids in which the polyps are not protected by a skeletal cup—*Bougainvillea*, *Cordylophora*, *Hydra*.

Class II. **Scyphozoa.**—Coelenterates in which the dominant phase is the "Medusa" or "Jelly-fish." The medusa may develop direct from a fertilised egg, as in *Pelagia*, but in most cases it is formed by the repeated transverse division of a small hydra-like but wide-mouthed "scyphistoma." The sexual cells are discharged first within the body-cavity.

Aurelia, with many short marginal tentacles.
Pelagia, with eight marginal tentacles.
Chrysaora, with many long marginal tentacles.
Rhizostoma, with no marginal tentacles.

Class III. **Ctenophora.**—Forms with transparent jelly-like bodies somewhat resembling jelly-fish, but differing from all other Coelenterates in having no nematocysts. Also they have peculiar and characteristic plates or "combs" of cilia fused together in

short bands arranged in eight longitudinal series; by the movement of these they swim through the water.

Hormiphora, a Mediterranean form.
Pleurobrachia, the British Sea-gooseberry.
Beroë, larger British form, thimble-shaped.
Cestus veneris, "Venus' girdle," non-British.

Class IV. **Anthozoa** or **Actinozoa.**—Polyps in which the mouth-tube is inverted to form the gullet, and the body-cavity is partially divided by radial mesenteries on which the sex cells are developed.

Sub-class A. ZOANTHARIA.—Polyps with simple unbranched hollow tentacles, in number five or six or a multiple of five or six.

Order I. *Actiniaria* or "Sea-anemones."

II. *Madreparia* or "Stony Corals." Those having a calcareous skeleton.

III. *Antipatharia* or "Black Corals." Those having a branched horny axial skeleton extending throughout the colony.

Sub-class B. ALCYONARIA.—Polyps with eight pinnate tentacles and eight mesenteries.

Type 1. With spicules scattered in the mesoglæa of the tissue uniting the polyps, *e.g. Alcyonium*, "Sea Fingers."

2. With spicules covering to form a branched axis, *e.g. Corallium rubrum*, the Red Coral.

3. Spicules forming a series of connected tubes connected by horizontal platforms, each tube lodging a polyp, *e.g. Tubipora*, the Organ Pipe Coral. The beautiful Sea Fans (*Gorgonia*) and Sea Pens (*Pennatula*) also belong to this sub-class.

A SEA-WATER AQUARIUM.

Even if a student is living away from the sea and therefore cannot study the creatures in the most desirable way, *i.e.* in their own natural habitat, he may still make valuable observations by keeping common Sea-anemones in a small sea-water tank.

How to start a Sea-water Tank. The "tank" may be merely a deep earthenware basin, glazed inside; but a rectangular tank, all glass, or one specially made so that its joints will withstand the salt water, is desirable when possible.

Well-washed sea-sand or shingle may be put over the bottom of the tank to the depth of about two inches. It is important that the sand should first be well washed in a basin under a running tap until the water which runs off it remains quite clear, then it must be well dried, or else washed once in *sea-water*, before

putting it into the tank ; above this floor some kind of rockwork should be built up, so that the anemones can attach themselves at different levels. The sea-water, when added, should be poured on to a large rock or an inverted jar placed on the bottom, in order to avoid stirring up the sand.[1]

Next a few healthy pieces of the bright green *Ulva*, Sea-lettuce, or the dark green hair-like *Cladophora*, growing attached to a piece of rock or shell, should be introduced; these will help in the aeration of the water.[2] Red and brown seaweeds are of little use for this purpose and rapidly decay, so they should be avoided.

The aquarium should stand, if possible, in a north window, so that it gets plenty of light, and yet not the direct rays of the sun, for these cause the too rapid development of microscopic green Algae over glass and stone. Three sides of the tank should be shaded with a dark curtain, and the top should be covered with glass, so that dust does not collect and form a scum over the surface of the water ; it is well to syringe the water with a small glass syringe with several terminal pores,[3] in order to drive air down into it. As the water evaporates, sufficient *fresh* (rain or tap) water must be added, to keep the density of the water constant. This should be poured in, very gently, a very little at a time, and then at once mixed with the salt water by stirring it with a glass rod.

Sea water that has become impure, or green from the growth of Algae, may be purified by filtering[4] then storing away in stone jars in a cool dark cupboard for some weeks. Dead animals should be removed with wooden forceps; the hand should never be put into the water.

When all is ready, the desired inmates of the tank may be introduced into it. It is important not to overcrowd the space, and also to choose those anemones that thrive well in captivity. Most hardy kinds travel with impunity, just packed in a tin with plenty of damp seaweed—bladderwrack makes good packing ; but it is of course better, if possible, that they should be carried in a jar of sea-water. When they arrive they should be put first into a "quarantine" bowl of sea-water, supplied with plenty of rocks or stones to which they can fix themselves, and only those should be introduced into the large tank which appear quite healthy and which have attached themselves.

[1] For directions for making artificial sea-water see Appendix B.

[2] A simple, easily made little apparatus for keeping the water always well aerated is described in Appendix A.

[3] Such a syringe can be bought at a chemist's for about 2s. 6d.

[4] A suitable hydrometer for testing the density of the water can be obtained from Messrs. Griffin, Kingsway, London, or other dealers.

Anemones suitable for the Tank. Anemones easy to procure and to keep in health are the beautiful Plumose Anemones (*Actinoloba dianthus*), common on the East Coast in deep water—they are large, pale-pink or white forms with frilled tentacles; also the Common Smooth or Beadlet Anemone (*Actinia mesembryanthemum*), the form described on p. 48; and the Daisy Anemone (*Sagartia bellis*), common on the coasts of Devon and Cornwall, but rather difficult to obtain, as it is wont to inhabit a hole in a rock into which it can completely withdraw itself. It is a curious form, with relatively narrow column and a spreading disc at the top, three or four times the diameter of the column.

Many other anemones may be kept, but it is well to begin with only two or three kinds at first; the Plumose Anemone lives best by itself, for when with other kinds of anemones it may get "bad-tempered" and shoot out "acontia" at the others when it comes into contact with them, and discharge mucus, so that none of them thrive.

The anemones should be fed on little pieces of raw or cooked beef, or the flesh of shrimps; the morsel should be held in wooden forceps[1] just over the anemone until it seizes it with its tentacles. All uneaten particles of meat should be carefully removed from the water.

During the first fortnight several of the anemones will very possibly die, but those that are left at the end of this time may live for years, and will reproduce freely. The little new anemones may often be observed in the process of being discharged from the mouth of a large anemone, and then going off to fix themselves in some far corner to begin their own lives. Sometimes a mere fragment of the column of an anemone, which has become detached when the anemone moved, may be seen to develop into a perfect individual; this frequently occurs in the Plumose Anemone.

A more extended study of Sea-anemones should be made on some rocky coast where they are abundant, such as many parts of Devon and Cornwall. "Finds" may be identified by reference to Gosse's *History of British Sea Anemones and Corals* (1866), which is still the standard work on the subject.

The *Plymouth Aquarium Guide* also is helpful.

[1] Convenient long wooden forceps can be bought of any dealer; they can be made without much difficulty (see Appendix C).

CHAPTER IV

PHYLUM III.: PORIFERA (SPONGES) √

SPONGES are animals which are often mistaken for plants, for when full grown they are fixed to a rock and they have no easily recognisable animal characteristics; indeed, some of them even have the green colour characteristic of plants, though this is exceptional (see p. 59). When young, however, they all live a free-swimming, active life for a few days (see p. 60), and when fixed later they all feed holozoically.

The body of a sponge is composed of many cells lying in close contact with one another, and usually forming a yellowish asymmetrical mass of varying size, which is fixed to a rock or seaweed, and which is practically motionless, though it may shrink slightly if touched; if squeezed, it is found to be compressible and yet tough, regaining its former shape when the pressure is removed. The surface of the sponge is dotted over with minute pores, and one or more larger openings known as *oscula* also occur. Sponges live always submerged in water, and if a few grains of some pigment such as carmine are dropped in the water near them, it will be seen that the grains are drawn *into* the minute "inhalent" pores, and also that they are driven *away from* the larger "oscula." This current of water is produced by

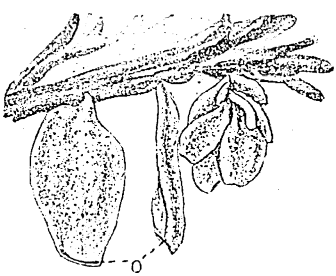

FIG. 27.—The Purse Sponge (*Grantia compressa*) (natural size), attached to a branch of seaweed.

o, Oscula.

the lashing of the protoplasmic threads or flagella, possessed by certain of the cells within the body (see Fig. 29), and it carries into the body both the oxygen necessary for respiration and also the decaying organic matter which probably serves as food.

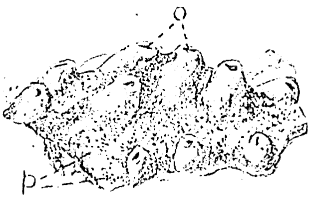

FIG. 28.—The Bread-crumb Sponge (*Halichondria panicea*) (natural size). *o*, Oscula; *p*, inhalent pores.

The form of the body varies very much. Sometimes it has the shape of a little flattened bag, with usually one osculum only, as in the Purse sponge, *Grantia compressa* (see Fig. 27); or it may form a branched finger-like mass, as in the common *Chalina oculata*, often thrown up on the beach after storms; or it may form encrusting masses with many oscula, each raised on a little projecting crater-like process, as in the Crumb-of-bread sponge, *Halichondria* (Fig. 28), which is common on rocks and weeds even above low-tide mark; others again form much larger and more complex bodies, as in the Bath Sponges, which are found chiefly in the Mediterranean Sea, and also off the West Indies.

In all cases the sponge-body is found to have a certain general type of structure, and a similar differentiation of tissues.

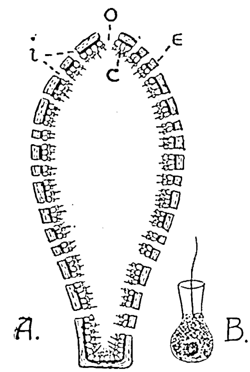

FIG. 29.

A, Diagrammatic representation of a longitudinal section through a sponge of simple Ascon type; *e*, ectoderm; *c*, collar cells; *i*, inhalent pores; *o*, osculum. *B*, one collar cell, enlarged.

Microscopic Structure. Ascon Type. In the simplest sponge-body the cells are so arranged that they form two distinct layers, surrounding a single cavity, which opens to the exterior by the osculum—but the osculum, it must be remembered, is not a *mouth*, but an aperture for the casting out of the water taken in through the pores all over the walls. This is the "Ascon" type of sponge.

The outer layer of cells corresponds to the skin cells (ectoderm) of Hydra; the inner cells correspond to the

endoderm of Hydra, but the latter are peculiar in sponges in being all very definitely flagellate, and also the cells bearing the flagella have a peculiar little projecting transparent tube round the base of each flagellum, whence they are called "collar cells." The whole central cavity in these simplest forms is lined with collar cells; between the ectoderm and endoderm is a gelatinous layer, the *mesogloea*; and embedded in this mesogloea are found the *spicules* which are so very characteristic of sponges and give them their tough texture. These spicules are of very varied shapes in different sponges (Fig. 30); in sponges of the Ascon type they are usually three-rayed and calcareous.

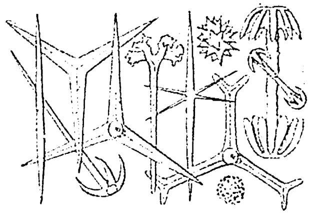

FIG. 30.—Various forms of Sponge Spicules much magnified (from Parker and Haswell).

This very simple Ascon type of structure is found in no *adult* British sponge, but is a stage passed through by some of them, e.g. *Clathrina blanca*, the White Lattice Sponge, which has at this stage a minute vase-like body about $\frac{1}{10}$th of an inch high, similar in structure to that shown in Fig. 29. Later the sponge branches in a complicated way, forming a reticulate sponge body with several oscula.

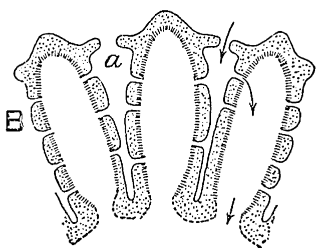

FIG. 31.—Cross-section through part of the wall of a Sycon.

a, Incurrent canal; the collar cells of the radial chambers are shown by short parallel lines (after Korschelt and Heider).

Sycon Type. In *Sycon*, a British sponge to be found on the south coast, there is still only one single central chamber, but the wall is much thicker, and from the central cavity lateral branches extend regularly and radially into the wall; the flagellate collar cells are now restricted to these radial extensions of the central cavity, which is itself lined merely by flattened endodermal cells (Fig. 31).

A further complication is introduced by the outer skin

cells being pushed in between two adjacent flagellate chambers, so that the external lateral pores open into a long narrow cavity which runs inwards between the flagellate chambers, and communicates with them laterally (Fig. 31, *a*). The water sucked in by the inhalent pores then passes down an incurrent canal, then on into a flagellate chamber, and finally into the central cavity and out of the osculum.

In Sycons, as in Ascons, many spicules are present which are calcareous, but they are four-rayed, or consist of needle-like structures pointed at both ends.

Sycon ciliatum is very common round our coasts; it forms little whitish oval sacs one or two inches high, with a ring of silvery spicules round the osculum.

Sycon, *Clathrina*, and *Grantia* all belong to the class *Calcarea*, which includes all those sponges in which the spicules are formed of carbonate of lime.

Six-rayed or Glassy Sponges. Certain sponges are known as *Six-rayed* or *glassy sponges*, because the spicules are siliceous instead of being calcareous, and they are typically six-rayed, though modifications of the six-rayed type may occur. These are all deep-sea forms, and are moored to the sea floor by a tuft of rooting spicules. Many of them have a very beautiful symmetrical structure, such as is seen in the well-known Venus' Flower-basket. In these forms, as in Sycon, the body-cavity is comparatively simple, with a single central space and thimble-shaped lateral extensions of it in the body-wall.

Common Sponges. In Common Sponges (*Demospongiae*) the structure is much more complicated, owing to the fact that the flagellate radial chambers, which extend from the central cavity, have become narrower and branched; also, in many, the flagellate cells have become confined to special little chambers in the radial canals.

Further complication is introduced by the original simple body having become much branched and all the branches having fused together, so that there may be a great many oscula scattered over the surface of the sponge as well as the very numerous smaller inhalent pores.

Bath Sponges. In most of these complex sponges the skeletal part consists of siliceous spicules, with one or four rays. These may occur alone or combined with a

network of horny or silky threads, formed of a substance known as *spongin.* In common *Bath Sponges* the spongin alone is present, forming the tough supporting skeleton which we buy as a toilet sponge.

In the best cup-shaped Turkey sponges these fibres are specially soft and fine, and the pores are so small that we do not find in them the sand and shells which so often get lodged inside the larger, coarser bath sponges.

These sponges all live in deep water, whence they are obtained by divers, or by means of long-handled pronged forks with which they are speared from boats. The living sponges are covered and penetrated throughout by the slimy living tissues, and it is only after these have decayed and the horny skeleton has been washed free from them, that the sponge is ready for household use.

Freshwater Sponges. There are two British freshwater sponges, both of which are peculiar in developing abundance of chlorophyll[1] if growing in a light spot; if in the shade, they are a buff colour.

Ephydatia (= *Spongilla*) *fluviatilis* is often very abundant in rivers and canals, forming massive, dull green or yellow, slimy encrustations on any old submerged timber, or growing on the banks; sometimes its surface is produced into a number of short leaf-like lobes. In the autumn it produces freely by means of "gemmules" (see below).

Spongilla lacustris, the Pond Sponge, also forms encrusting masses, but from these grow out oval or finger-like processes. It is a brighter green than the River Sponge, and its substance is denser and is made of coarser fibres.

Reproduction in Sponges. Since these big complex sponges are formed by the branching of a simple sac-like form, they may be looked upon as formed of a colony of sponge individuals, living together in a united mass. Sometimes a little group of cells will become detached from such a sponge as a bud or *gemmule*, which will develop into a new separate individual; this is specially frequent in the common green freshwater sponge, *Spongilla*, where each gemmule is about the size of a pin's head, and is surrounded by a thick horny capsule strengthened by siliceous spicules. Inside this capsule the gemmule persists through the winter, giving rise to

[1] See footnote, p. 28.

a new sponge in the spring. If one such gemmule is removed from the parent, and kept in a covered watch-glass of water in a sunny spot, after a few days an active young sponge will be obtained, which is so transparent that the currents of water passing through its body can be readily traced if the water is coloured with carmine.

Sponges also multiply by a sexual process similar to that in Hydra, *i.e.* as a result of the fertilisation of an egg cell by a sperm cell. The gametes are developed in the mesogloea, usually in the autumn, and the egg remains hidden in the tissues of the parent during the first stages of its development, making its way out of an osculum as an independent organism only when it has developed into an oval multicellular ciliated body; this young form swims freely in the water for several days, but it finally fixes itself to some object, and for the rest of its life lives a stationary existence, gradually growing into a complex sponge like its parent.

The Source of Silica in Sponges. The power possessed by sponges of extracting silica from the water in which they live is remarkable, for the amount of this found in solution in sea-water is very insignificant, being about $1\frac{1}{2}$ parts of silica in 100,000 of water. It is said that to form 1 oz. of the spicules at least one ton of water must pass through the body of the sponge. The same power of extracting the silica is also exercised by certain Protozoa (the Radiolaria), and by the little microscopic plant forms, the Diatoms. It is interesting to note that the formation of the flints so often found embedded in chalk rock is said to be connected with the remains of sponges.

Relationships of the Porifera. It is clear from the above account that Porifera resemble Coelenterata in having the two tissues, ectoderm and endoderm, well developed, and in having mesogloea separating them; yet they are peculiar in very many points, such as the presence of inhalent pores and oscula, the course of the water current in the body, the possession of the singular "collar cells," and the characteristic sponge spicules formed in the mesogloea of most of them. Hence they are classed in a separate phylum. Probably they have been quite independently derived from a Protozoan ancestor, and are more primitive than Coelenterates, though they have been described here after the latter, for their very

peculiar structure is then more evident and is more fully appreciated. Their connection with the Protozoa becomes more apparent when the order of the *Choanoflagellata* amongst the Protozoa is studied,[1] for these forms have the same curious "collar" round the base of the flagellum which is so characteristic of the flagellate cells in Sponges; also in one Protozoan form, *Protero-spongia*,[1] a number of individuals are united together in an irregular flat colony by a gelatinous substance, those individuals on the outside being all typical collared flagellate forms, whilst those in the centre are non-flagellate and have amœboid movement. Such Amœboid cells are also found in the mesogloea of Sponges. Sponges, however, are much more advanced and complex than any Protozoa, and differ from them in the important characteristic of their mode of development from an egg cell, in which they approach the Coelenterates, though they are too peculiar in other ways, as has been shown, to be classed with them.

Classification of the Sponges mentioned in Chapter IV.

Class I. CALCAREA.—Marine Calcareous Sponges.
Grantia compressa, the Purse Sponge.
Clathrina blanca, the White Lattice Sponge.
Sycon ciliatum, the Ciliated Sycon.

II. HEXACTINELLIDA.—Six-rayed or Glassy Sponges.
Euplectella aspergillum, Venus' Flower-basket.

III. DEMOSPONGIAE.—Common Sponges.
(1) Those with siliceous spicules which may have 1–4 rays but never 6. They may have also a supportive skeleton of horny or silky threads of Spongin.
Halichondria panicea, the Bread-crumb Sponge.
Ephydatia (Spongilla) fluviatilis, the River Sponge.
Chalina oculata.
Cliona celata, the Boring Sponge.

(2) Those with a skeleton of horny "spongin" fibres alone.
Euspongia officinalis, the Turkey Cup Sponge.
Hippospongia equina, the Common Bath Sponge.

PRACTICAL WORK ON SPONGES

1. Obtain a few small specimens of a freshwater sponge, and place them in a vessel of water. Drop in some fine carmine

[1] See article "Protozoa," *Encylopædia Britannica.*

powder, in order to make visible the currents produced in the water by the living sponge.

Break one piece of sponge open and look for the little yellow spherical gemmules; keep them separate and watch their development into new sponges.

2. Collect sponges at the seaside: they will be found attached to rocks, shells, seaweeds, or submerged timber. Sketch any well-defined forms, and identify by reference to Bowerbank's *Monograph of British Spongiadæ* (4 vols.; vol. iii. gives pictures of many of the commonest sponges).

3. Treat a small piece of various common sponges with nitric acid; this will destroy the organic matter, leaving a sediment of siliceous spicules, which after careful washing should be examined under the microscope and the kind of spicule characteristic of the different sponges noted.

4. Examine the collection of sponges in the nearest Natural History Museum.

CHAPTER V

PHYLUM IV.: ECHINODERMATA

(Starfishes, Sea-urchins, etc.)

The Echinoderms are multicellular animals, distinguished from the Coelenterates by the presence in them of a distinct body-cavity or *coelom* lying outside the digestive or alimentary canal, and containing the vital organs of the body.

They are usually five-rayed and radially symmetrical forms, with a skin hardened by small calcareous plates and spines. A unique character, found only in this phylum, is the presence of a peculiar water-vascular system, by means of which water can be taken into the body and pumped into the "tube-feet," which in many of the Echinoderms are the chief organs of locomotion. There is, however, no well-defined blood-vascular or excretory system. The phylum is large and varied, and is divided into five classes, all of which are marine.

Class I.: ASTEROIDEA

Type: **The Common Starfish** (*Asterias rubens*).

This *Starfish* is well known on our coasts, and can be easily recognised by its five thick rays or arms, covered with little limy plates bearing small spines; one specially well-marked line of spines runs down the centre of the upper surface of each arm, thus distinguishing it from another species (*Asterias glacialis*), which has less numerous and larger spines arranged in three to five special lines down the arms. When lifted up, the arms of the Common Starfish droop limply, a character

which prevents it from being confused with the smaller, stiff starfish *Henricia*, which is almost equally common.

External form. Dorsal Surface. All these Starfishes live on the sea-floor, crawling over the rocks and sand amongst the seaweed. In essential structure all starfishes are very similar. The body consists of a central disc-like portion with five radiating arms, which are all alike both in

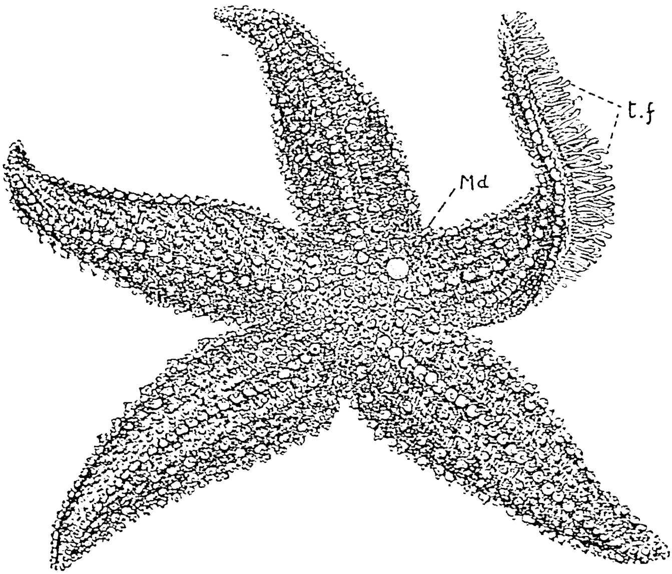

FIG. 32.—*Asterias rubens* (life-size).

Dorsal view · one arm is raised to show the tube-feet, *tf*, on the ventral surface ; *md*, madreporite.

external and internal structure, and all of which are equally capable of moving forwards and dragging the rest of the body after them. The surface of the body feels rough to the touch, for in the body-wall are embedded very numerous small calcareous plates or "ossicles," which protect the body and yet do not impede its motion, as they can move freely one on another. Many of these plates bear small simple spines, and amongst these may be seen small pincer-like bodies mounted on short stalks; these are known as "pedicellariae" (Fig.

33, *p*); under a lens they can be seen snapping together and opening again, and it is thought their function may be to keep the body clear of the small particles of foreign matter that might so easily catch and accumulate between the spines.

To one side of the central disc, between the bases of two arms, may be seen a small calcareous perforated plate known as the *Madreporite* (Fig. 33, *md*), the function of which is explained later (see p. 68).

Ventral Surface. On turning the starfish over, it will be seen that a deep groove runs from the tip of each arm to the centre of the disc where the large mouth is situated. Each groove contains two double rows

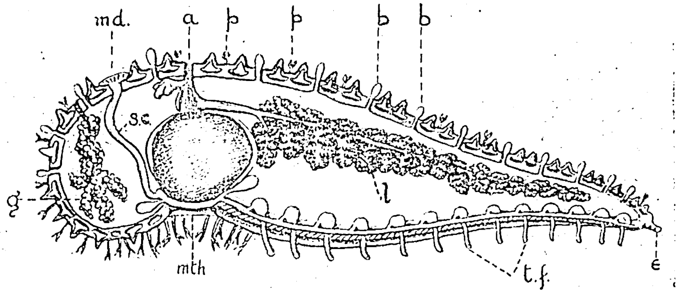

FIG. 33.—Section through the Disc and one of the Arms of a Starfish. (Diagrammatic.)

mth, Mouth; *a*, anus; *p*, pedicellariae; *tf*, tube-feet; *b*, respiratory vesicles; *sc*, stone canal; *md*, madreporite; *g*, generative organ; *l*, one branch of digestive sac or "liver-gland"; *e*, eye-spot. (Nervous system omitted.)

of transparent finger-like "tube-feet," the tips of which form suckers, that enable a starfish to adhere very closely to a rock, and which are also used in its characteristic slow motion over a vertical or horizontal surface. By means of them the starfish can turn itself over if placed back downwards.

These tube-feet vary greatly in length and shape, for they can be extended or contracted at will, owing to the action of the peculiar water-vascular system (see p. 68).

Movement. When the creature wishes to move in any special direction, the tube-feet of the arm on that side all extend and attach themselves to some object by the

suckers at their tips; then, when firmly fixed, they contract and thus draw the body forward in the required direction; they then become detached and the same performance is repeated.

To understand more clearly the action of these tube-feet a knowledge of the internal structure of the creature is necessary. The best way of gaining this is by a simple dissection of a specimen.[1]

Internal Structure. Alimentary Canal. Such a dissection will first of all disclose the alimentary canal leading from the rather wide mouth on the ventral side to a very minute aperture, the anus, near the centre of the dorsal surface (Fig. 33, *a*). This alimentary canal is by no means a uniform tube, but is modified into widely differing portions with varying functions. The mouth leads by a very short gullet into a large round stomach, just above which, at the base of the five arms, five large branches are given off. Each branch divides to form two long closed digestive sacs which lie in the cavity of the corresponding arm (Fig. 33, *l*). Two other small processes are given off from the intestine above the stomach near the anus, one of which is shown in Fig. 33.

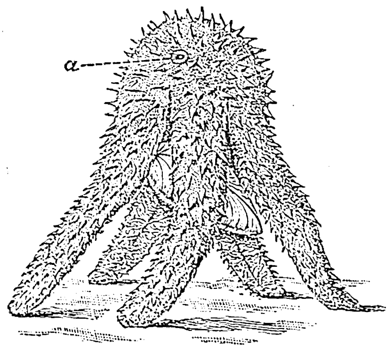

FIG. 34.—View of a Starfish (*Echinaster*) devouring a Mussel. (From the *Cambridge Natural History.*)

a, The madreporite.

Food. The starfish feeds on small sea-snails, also on oysters, scallops, mussels, and other bivalves. The fact that the latter forms may be too large for it to swallow is in no way a hindrance, for in such a case the starfish first crawls right on to the top of the bivalve, then pulls asunder the two valves with its suckers, and finally protrudes its stomach right through its own mouth, turning it inside out and spreading it over its prey, so that it partially digests its food outside of its body instead of inside!

[1] See practical notes, page 76.

General Body-cavity and its Contents. The cavity surrounding the alimentary canal is the body-cavity or "coelom," in which lie all the other organs of the body. These are found to have a radial symmetry corresponding to the external symmetry; *e.g.* there is a *water-vascular system* and a *nervous system*, each including a circum-oral ring and a radial extension into each arm. (These are omitted in Fig. 33.) Each radial nerve-cord is connected with a little red *eye-spot* lying just below the minute tentacle below the tip of each arm, and frequently exposed by the upturning of the arm (Fig. 33, *e*). The eye-spot is a complex structure consisting of from one to two hundred little cup-shaped pockets, lined with visual cells and pigment.

The *generative* organs are likewise radially arranged, though they alternate with the arms instead of corresponding with them in position. The sexes are distinct; there are five pairs of ovaries or spermaries in each individual in between the bases of the arms (Fig. 33, *g*); each pair has a separate duct which opens by a pore on the dorsal surface of the body. The eggs are fertilised in the water after having been discharged from the ovary.

Respiration. Respiration seems to be chiefly effected by means of little thin-walled outgrowths of the skin, which project from the upper surface and the sides of the starfish. They can be clearly seen when the starfish is under water (Fig. 33, *b*). The cavity of these is continuous with the body-cavity, and the oxygen from the sea-water can diffuse through them to the fluid which fills the body-cavity, and so pass to all parts of the body. There seems to be no definite blood-vascular system, though certain canals and spaces that occur were originally wrongly described as such.

Water-vascular System. Within the body-cavity will also be found the curious water-vascular system on which depends the action of the tube-feet, and which is only found in the group of the Echinoderms.

Each tube-foot is seen to pass through the external body-wall and to swell inside into a little vesicle or "ampulla" (Fig. 33, *tf*). Each vesicle is connected by a very short tube to a radial canal which extends the whole length of the arm, and the five radial canals unite in a circular ring just above the mouth (Fig. 33, *mth*). This ring is known as the "ambulacral ring," and it connects with the exterior by a single tube with

hard calcified walls, the *stone canal* (Fig. 33, *sc*). The stone canal ends in the little perforated plate, the madreporite, which will have already been observed in the external examination of the starfish. Through the madreporite, water enters and fills the whole system of tubes and ampullae ; the latter can be contracted at will, forcing the water from them into the tube-feet and so extending them ; then again by a contraction of the muscles of the tube-feet the water is driven back into the ampullae and the feet consequently contracted. In this way the tube-feet are brought into use in locomotion as explained previously.

Regeneration. It is obvious from the foregoing account that the radial structure which is so marked externally extends to nearly all the internal organs, the stone canal being the only important exception. This fact helps to explain the curious power of regeneration possessed by a starfish. It is well known that any arm detached from its body can grow into a fresh five-rayed creature once more, for it contains all the vital organs necessary for life and growth.

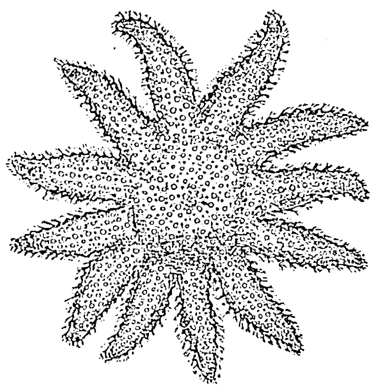

FIG. 35.—The Sun-star (*Solaster papposus*). × ½.

Other Asteroidea.

Sun-stars. Besides the common five-rayed starfish, we find on our coasts, living between tide marks, the beautiful rosy Sun-stars (*Solaster papposus*), each having twelve or more short rays. In both Star-fish and Sun-stars and in all members of the class of the Echinoderms known as *Asteroidea*, the digestive organ is prolonged into the arms.

Class II. : OPHIUROIDEA

Brittle-stars. The *Brittle-stars* or *Ophiuroids* differ from the Asteroids in their thinner, longer arms, which are sharply separated from the disc, and which contain no

prolongation of the digestive system, all the chief organs of the body being confined to the central disc. The arms are very flexible and yet at the same time brittle; the animal readily snaps them off if annoyed. A brittle-star is altogether a much more active creature than a starfish, moving, not by means of its tube-feet, which in *Ophiuroids* have probably a respiratory function, but by the muscular movements of its very active arms or rays.

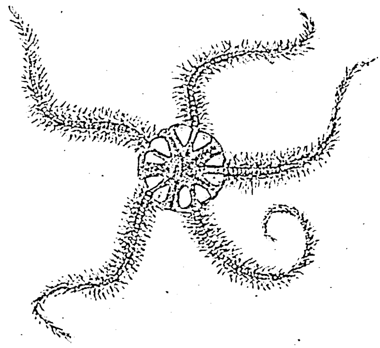

FIG. 36.—Common Brittle-star (*Ophiothrix fragilis*).

Class III.: ECHINOIDEA

Sea-urchins. *Sea-urchins*, or Echinoids, occur plentifully on our coasts, and the small purple-tipped urchin (*Echinus miliaris*) can easily be kept alive in a sea-water tank. In these forms the body is no longer rayed, but is apple-shaped, varying in horizontal diameter from several inches in the case of the Common Urchin (*Echinus esculentus*) to about one inch in the purple-tipped species which is common beyond low-water mark on rocky coasts.

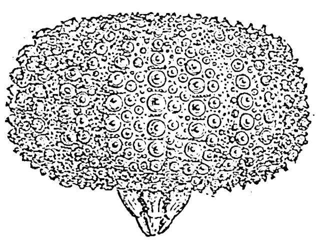

FIG. 37.—Shell of Sea-urchin with teeth protruding.

In all Sea-urchins the body is covered with a continuous hard shell, except where soft skin surrounds the mouth. This shell is covered with many movable spines, and on these, with the aid of some of the five double rows of beautiful tube-feet which can be extended to a much greater length than in the starfish, the Urchin crawls along the sea-bottom, mouth downwards.

Spines and Pedicellariae. Each spine is concave at the base and the concavity fits over a little projecting knob on the shell, making a very flexible ball-and-socket joint which has a special muscle supply. Amongst the spines which cover a sea-urchin's shell are many little *pedicellariae* which are more varied and more developed than those of a starfish (see pp. 64-5).

Practically all have a rod-like base which articulates with a boss on the shell. This rod bears at its free tip three movable jaw-like pieces which vary considerably. Some, with flexible stalks, are beset with little teeth; the use of this kind seems to be to protect the body from infection by the small active larvae of certain parasitic creatures; before they can settle they are snapped up by these jaws and destroyed.

In a second kind the stalk is stiff and the three jaws are twice as large as those described above, and each ends in a curved tip in connection with a poison gland below; when attacked by such an enemy as a starfish these jaws are brought into play; they seize the tube-feet of the aggressor and cause it rapidly to retreat; the jaws break off as the tube-feet are withdrawn, and consequently, if the starfish returns again and again to the attack, it sometimes happens finally that the Urchin has no weapons left and is at the mercy of its enemy.

Much smaller pedicellariae function either in clearing away any particles of dirt that may fall between the spines or in holding small creatures that are of food value until they can be seized by the tube-feet and conveyed to the mouth. It is a curious and interesting sight to watch a live Sea-urchin and see all the little grappling organs at work, opening and then snapping together with great activity.

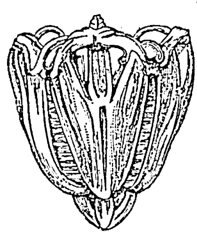

FIG. 38.
"Aristotle's Lantern."

Teeth. The mouth contains a complicated tooth-bearing structure consisting mainly of five chisel-edged teeth which, together with the calcareous ossicles which support them and the muscles which move them, form the structure known as *Aristotle's lantern*. Owing to the extensible soft membrane that surrounds the mouth, the "Lantern" can be projected beyond it, and so the teeth can be given free play to crop

the sea-weed which, together with some animal matter, forms the food of the Urchin. This lantern is very complex, consisting of twenty-five separate pieces arranged in five sets of five. Its detailed description is out of place here, but it is an interesting piece of work to try to dissect it out entire and study its mechanism.

Besides these two commonest Sea-urchins or Sea-eggs, which are more or less spherical in shape and radially symmetrical, there are certain forms with a more flattened shell and bilateral symmetry which are known as *Heart Urchins.*

Heart Urchins. These are usually to be found buried some inches deep in the mud or sand beyond low-water mark, each in little burrows opening to the water by a narrow channel. They can be dug out with a spade.

The commonest on our coast is *Echinocardium cordatum.* When first exposed this species is covered with silky golden spines which lie flat over the body, but the colour soon fades after death. The shell is oval, but flattened on the under surface; so across this, near the centre but slightly towards the front, depressed end of the shell, runs a curved mouth. There are no jaws forming a "lantern" here, for these creatures do not walk about cropping the seaweeds as do their more active relations, but remain more or less motionless in their burrows, sending up through the channel above them one of their specially long tube-feet; this grasps what it can of the surface sand which is rich in little living organisms, and brings the mixed morsel of food down to the groove which leads to the mouth, and to which it is carried by other tube-feet and finally swallowed.[1] When the creature requires to move through the sand or to burrow in it, it uses the special

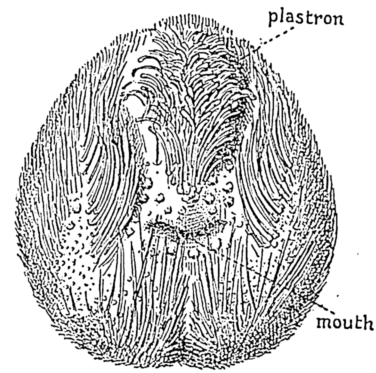

FIG. 39.—The Heart Urchin (*Echinocardium cordatum*). Oral view (× 1).

[1] See *Cambridge Natural History*, vol. i. p. 352.

long curved spines on the lower surface behind the mouth, the region known as the "plastron" (see Fig. 39).

Spatangus purpureus is the Purple Heart Urchin, which inhabits deeper waters, though it is frequently cast ashore after a storm; its colour and the greater length and curvature of its strong spines serve to distinguish it from the Common Heart Urchin.

Cake Urchins. The Cake Urchins are much flattened forms in which some of the dorsal tube-feet are modified to form gills. The only British species is *Echinocyamus pusillus*, a little flat, oval creature not more than an inch across; it is found in shallow, sandy waters.

Class IV.: HOLOTHUROIDEA

Sea-cucumbers. The Echinoderms also include the curious tough-bodied *Sea-cucumbers* or *Holothurians*, which at first sight look like thick worms rather than relatives of the sea-urchins and starfishes. Nevertheless, on examination, they are found to possess isolated calcareous deposits in the leathery skin, and to have five rows of tube-feet down the elongated body, though these tube-feet are only very slightly retractile; round the mouth, at one end of the body, is a circle of contractile tentacles; there is therefore an approach towards radial symmetry externally, but this is obscure internally.

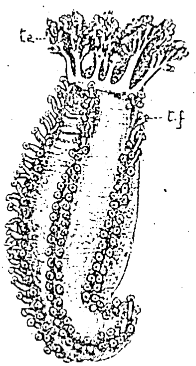

FIG. 40.—Sea-cucumber (*Cucumaria lactea*).
te, Tentacles; *tf*, tube-feet.

The Sea-cucumber perhaps most commonly found on our coasts is the little white or brown *Cucumaria lactea* (Fig. 40). These curious little creatures live at the sea-bottom, usually beyond low-tide mark, crawling slowly over the ground, and feeding on small molluscs and crustaceans which they catch on their sticky, slimy tentacles; each tentacle in turn is pushed into the mouth, which closes on it, stripping it of all food matter as it is once more pulled out again.

The Cotton Spinner. Another larger British deep-water form is the Cotton Spinner (*Holothuria nigra*); this may grow to the length of a foot, and has a dark brown upper side and a yellow lower side on which it crawls, only the tube-feet of the under side forming suckers to aid in locomotion. The "Cotton Spinner" has gained its name from its power of ejecting from its anus, when in danger, certain of its viscera; the mucus contained in some of these immediately swells up in the water and splits into a mass of white threads large enough to entangle a creature much larger than itself, and whilst its enemy struggles in its toils the spinner escapes. If left in peace it can subsequently repair the damage done to itself by this peculiar method of defensive self-mutilation.

Synapta inhaerens. An allied British species, *Synapta inhaerens*, may also be obtained by digging in the sand below low-tide mark; it is a pink, transparent worm-like creature with five narrow lighter longitudinal stripes. Its length is about 3 inches, and it has round the mouth a circle of twelve tentacles, each with six or seven papillae on either side. These tentacles seem to be nearly continuously feeling around for the small animals and plants on which *Synapta* feeds; their clinging power can be felt if the papillae are touched, and microscopic investigation discloses little anchors of lime projecting from the skin which fix into any soft objects they touch.

Sea-cucumbers are well known in China, where they are called "trepangs," and form a much relished article of food.

Class V.: CRINOIDEA

Sea-lilies or Feather Stars. The only other group of Echinoderms is that of the *Feather Stars* or *Sea-lilies*, the Crinoidea. This is a group which used to be much larger and more important in past ages; now it consists of a few forms only, living at great depths in the sea. They are nearly all sedentary, consisting of calcareous disc-like bodies, with branched segmented arms surrounding the mouth on the upper side of the body. In these cases the discs are attached to some object by a segmented calcareous stalk, as in *Pentacrinus*, one of the stalked "Sea-lilies." Some of them are stalked only when young, and move freely about when adults

with a creeping or gentle swimming motion; such forms are found in comparatively shallow water — the Rosy Feather Star (*Antedon rosacea*) may be dredged up from a depth of only ten fathoms, round the south-west coast of England. Fig. 41 shows this form in its young stage when it is still attached by a stalk. Fig. 42 shows an adult form anchoring itself to a rock by means of a whorl of little whip-like processes or "cirri" which spring from a small stump, all that the adult retains of its larval

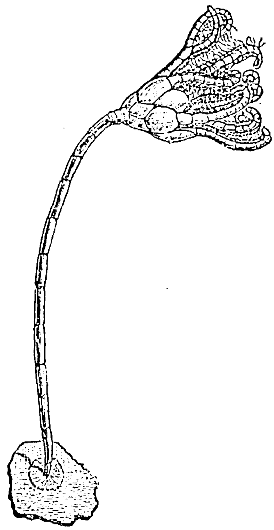

FIG. 41. — *Antedon rosacea.* Young stalked stage. (From the *British Museum Guide to the Starfish Gallery.*)

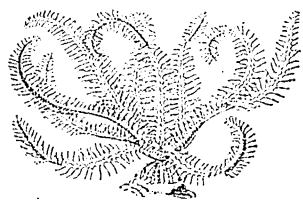

FIG. 42. — *Antedon.* Side view of adult animal. (Leuckart and Nitsche.)

stalk. It can at will release its hold and swim away, waving its arms gently about, five being raised and five depressed with a regular rhythmical motion.

Echinoderm development. All Echinoderms have a very peculiar development. From the egg arises a minute, ciliated, free-swimming larva, with bilateral symmetry, which only gradually, by a very strange form of metamorphosis, becomes converted into the adult form with radial symmetry. The study of the development is specially interesting, for it gives indications of the directions in which we may look for links between Echinoderms and other animals, but it is a study beyond the scope of this book, and the student is therefore referred to more comprehensive works.[1]

In many ways the Echinoderms form a very isolated

[1] *The Cambridge Natural History*, vol. i. chap. xxi.; or *A Text-Book of Zoology*, by T. J. Parker and W. A. Haswell.

group, the relationships of which it is difficult to trace with any certainty. An interesting probable link, however, between them and the Vertebrates may be seen in the curious burrowing worm-like form *Balanoglossus*, which has a ciliated free-swimming larva almost identical with that found amongst Echinoderms, but which, nevertheless, loses any resemblance to this group in its adult stages, developing gill-slits and other features which seem to link it undoubtedly with primitive vertebrate animals.

History of Echinoderms. The Echinoderms are a very ancient group. Forms related to modern Crinoids existed in the Cambrian and Ordovician seas, which they shared only with other primitive invertebrate types such as Sponges, Graptolites (primitive Hydrozoa, possibly), Brachiopods (Lamp-shells), Trilobites (Crustacea), and some Mollusca. Later, from Silurian to Carboniferous times, stalked Crinoids were so numerous that their remains formed great beds of limestone, but gradually they dwindled until only eight genera of this once very large and varied class now exist. As they dwindled, the Sea-urchins and Starfish, the more active and aggressive types, became more prominent, and their fossils are very plentiful in the Cretaceous rocks, and also their living representatives are very numerous to-day.

Classification of Echinoderms mentioned in Chapter V.

Class I. Asteroidea.—*Asterias rubens*, the common Starfish.
Solaster papposus, the Sun-star.

„ II. Ophiuroidea.—*Ophiothrix fragilis*, the Brittle-star.

„ III. Echinoidea.—*Echinus esculentus*, the Common Sea-urchin.
Echinus miliaris, the Purple-tipped Urchin.
Echinocardium cordatum, the Heart Urchin.
Spatangus purpureus, the Purple Heart Urchin.
Echinocyamus pusillus, the Cake Urchin.

„ IV. Holothuroidea.—*Cucumaria lactea*, the Sea-cucumber.
Holothuria nigra, the Cotton Spinner.
Synapta inhaerens.

„ V. Crinoidea.—*Antedon rosacea*, the Feather Star.
Pentacrinus, a Sea-lily.

Practical Work on Echinoderms

In the Aquarium. A small *Starfish*, not more than 2 inches across, and a *Sea-urchin*, still smaller, can be quite well kept in the sea-water tank set up according to directions given on pp. 52-54. It is very important, however, not to overcrowd the tank; indeed it is best to keep Echinoderms alone, as they may attack other inmates of the same tank.

The Rosy Feather Star may be easily obtained by dredging, and it is an interesting and hardy inhabitant of a tank.

Both Starfishes and Sea-urchins can be fed on little sea molluscs, especially bivalves; they will also eat pieces of raw fish. If fed when they are crawling up the glass front of the tank, the food can be pushed between them and the glass and their method of feeding observed. Careful observations should be made on the external structure and habits of the live creatures.

Dissection of a Starfish. The skin covering the upper surface of the arms of a dead Starfish should be carefully cut away, leaving intact the small central part bearing the anus and madreporite. The form of the alimentary canal from mouth to anus can then be exposed by a little displacement of the structures which surround it.

The five large digestive sacs should be lifted up to expose the five pairs of reproductive organs which lie below them but alternate with them in position. The stone canal should be found, and as many points of structure as possible which are mentioned in the preceding chapter should be verified.

General Study. Specimens illustrative of each class of Echinoderms should be searched for at the seaside. Dredging is necessary to obtain Crinoids, but representatives of each of the other classes may be obtained in rock pools between tide-marks. Identifications can be made with the aid of Forbes's *British Starfishes and other Echinodermata* (1841), or by reference to *A Handbook of the Echinoderms of the British Isles* (Oxford Univ. Press, 1927, 38s.).

CHAPTER VI

PHYLUM V.: ANNELIDA OR RINGED WORMS

THIS group is one which used to be united with the Flat-worms, Thread-worms, and Ribbon-worms in the one large phylum Vermes, for there is a decided superficial resemblance between all these "worms." Examination, however, of their internal structure has disclosed such marked differences that they are now grouped in four different phyla.

The Annelida are here considered first, because they are by far the best known, including as they do common Earth-worms, Sea-worms, and Leeches.

They are all characterised by the elongated ringed body, the segmentation being not merely external, but extending to many of the internal organs. The coelom is well developed and segmented, definite blood-vascular and nervous systems are present, as well as very peculiar and distinctive paired excretory organs (nephridia) which may be repeated in each segment.

The only two classes of the Annelids that will be dealt with here are the Chaetopoda (the Bristle-worms) and the Hirudinea (the Leeches).

Class I.: CHAETOPODA

(THE BRISTLE-FOOTED RINGED WORMS)

Type: **The Earthworm** (*Lumbricus terrestris*).

Habitat. Earthworms are very widely distributed, and this special genus, *Lumbricus*, is common to North America, Europe, and North Asia. They are also to be found

in very varied situations, and do not seem to mind whether the soil they live in is rich or poor so long as it is moist. Moisture is an essential condition for their life, exposure to drought killing them most rapidly. They are therefore rare in dry sandy soil, and most common in a damp soil covered with short vegetation which protects the surface from the heat of the sun.

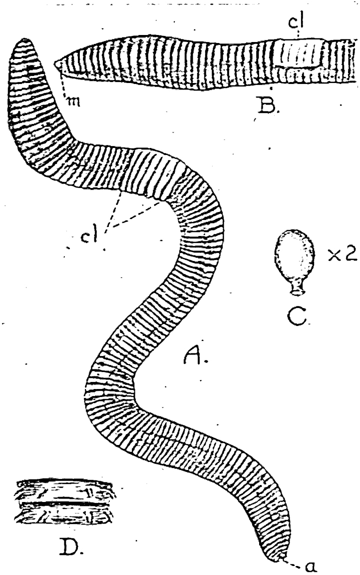

FIG. 43.—*Lumbricus terrestris.*

A, View from above. *B*, View from the side. *C*, Egg cocoon. *D*, Two segments seen from below to show the bristles or chaetae; *m*, mouth; *cl*, clitellum or "saddle"; *a*, anus.

External Appearance and Structure. The body is long and narrow, shaped like a cylinder, but tapering at each end, especially in front. It is covered with a soft, naked, slimy skin, which is slightly iridescent, owing to the fact that it is very finely striated. The red colour of a worm is due to the flesh below being reddened by its blood supply and showing through the transparent skin; the colour is darker dorsally than ventrally; the chief blood-vessel of the body can be clearly seen as a thin red line running from head to tail along the back; a ventral vessel is also distinguishable running below the alimentary canal.

The body is marked with a great number (120 to 180) of circular grooves. These external rings correspond to an internal segmentation of the body into chambers by delicate transverse plates of skin, most of the organs in one such chamber being duplicated in the next, so that the segmentation in these worms is not merely superficial, but extends to many of the vital organs of the body. Below the first

segment is the mouth (Fig. 43, *B*, *m*), a small crescent-shaped aperture, whilst the anus is an oval aperture in the last segment.

A little way behind the head (segments 32 to 37, usually) the top and sides of the body are somewhat thickened and swollen, forming the structure known as the *saddle* or *clitellum* (Fig. 43, *cl*). This swelling is due to the presence in this region of glands in the skin which secrete the mucous substance of which the egg capsule is made (see pp. 83-4). The size and appearance of the clitellum vary at different times of the year, and in worms of different ages.

Although at first sight the body of the worm appears smooth all over, if carefully examined the presence of four double rows of little bristles can easily be discovered, two rows placed ventrally and two laterally (Fig. 43, *D*). These can be seen if the worm is held up to the light and turned round so that the light catches the projecting bristles, or they can even more readily be felt if the worm is gently stroked from tail to head. These bristles, or "chaetae" as they are technically called, are of great use in locomotion; if a worm is placed on a piece of rough paper its method of movement can be easily observed. It is seen to stretch out the front part of its body, making it longer and thinner; the bristles are retracted and disappear from sight; next it contracts the front end, at the same time pressing the front bristles into the rough surface of the paper so that the body cannot slip back; as this takes place the hinder part lengthens, becomes free from the substratum, and is drawn up nearer to the head, and so alternate waves of elongation and contraction pass down the body, resulting in a forward movement of the whole body. The retraction and protrusion of the bristles can be seen, and the slight scratching made as they move over the paper is clearly audible.

Movement.

The power to move the body in this way is due to the development of special layers of muscles which lie just within the body-wall and are attached to it. One layer, that next below the skin, consists of muscles which run round the body, the circular muscles; these by their contraction, at any part of the body, cause that part to become longer and thinner. Within this layer is another of muscle fibres

running longitudinally, which by their contraction cause the body to shorten and thicken.

The Burrow. Earthworms live in burrows that run down almost perpendicularly into the earth. These, in very dry or cold weather, may penetrate to a depth of 6 or 7 feet, but usually end at about 18 to 20 inches below the surface. The burrow is made, if in soft soil, mainly by the mere pushing of the body through the earth, the thin tapering head end being inserted into some tiny crevice, and then the crevice enlarged by the swelling of the body; the habit of earthworms of swallowing soil aids also in the making of the burrow, especially in very compact soil. If the earth contains any organic matter this is absorbed as food, and the remaining soil is usually ejected at the surface of the ground from the end of the body, forming the well-known "worm castings." Sometimes some of the soil as it is ejected is pressed by the flattened tail against the sides of the burrow, and, being mixed with a viscid secretion from the worm's body, it forms a smooth firm lining to the tunnel which can easily be seen if a dry clod of earth, frequented by worms, is carefully broken in two. A liquid is said also to exude from the skin, which is antiseptic and protects the worm from any harmful bacteria in the soil.

The worms live in these burrows, rarely leaving them, except after very heavy rain, when they are said to desert them entirely, and to make fresh burrows. During the day-time they remain hidden, but at night they are very active, coming almost entirely out of their retreats, the tail just being kept in the mouth of the burrow so that at the slightest alarm a dart can quickly be made back into shelter. It is at this time that they obtain their supply of leaf food. **Food.** They move the exposed ends of their bodies over the ground all around until they touch some desirable object, such as a fallen leaf or flower. This they seize between upper and lower lip, and by a sucking action of the mouth the leaf is held and then drawn down into the burrow to a depth of two or three inches. There it is moistened with an alkaline fluid secreted by the skin, which discolours and softens it, acting on the starchy and proteid contents of the leaf, so that they are actually partially digested before being taken into the soft mouth, an unusual

procedure, apparently necessitated here by the dry hard nature of the fallen leaves which form a large part of the food of worms, especially during the autumn months.

At other times of the year, or in spots where leaves are scarce, worms seem to subsist almost entirely on the nourishment they obtain from the soil which they swallow. Most surface soil contains many minute spores, ova, seeds, larvae, and small living or dead creatures, all of which come as "grist" to the earthworm's "mill," for any necessary grinding of the food takes place in the hard-walled muscular "gizzard," an enlargement of the alimentary canal corresponding to a stomach, lying within segments 16 to 20 of the body. When a worm is feeding in this way, the "castings" on the surface are very numerous, whilst, where leaf food is plentiful, the castings are fewer and less conspicuous.

The Plugging of the Burrows. Besides obtaining leaves for food during the night, worms often actively exert themselves in plugging up the mouth of their burrows with leaf-stalks, leaves, or even small stones—the rustling of the dry leaves as they are drawn over the ground is sometimes distinctly audible; this is most noticeable in the autumn or early winter, and the habit is probably chiefly a protection against cold; in the summer, too, it lessens the danger of the burrows becoming too dry during the hot days, and also excludes certain enemies of the worm, such as parasitic flies, which might enter the burrow from above.

A most interesting account of the way in which the leaves are pulled into the burrows is given by Charles Darwin in his book, *Vegetable Mould and Earthworms.* From his numerous observations and experiments on this point, Darwin concluded that worms show a certain degree of intelligence in their mode of action, for a leaf is not at once drawn in, by whichever side happens to be nearest, but only after having been felt over by the sensitive head end of the worm's body. It is then nearly always seized by its narrowest part, which is usually, but not invariably, the apex of the leaf, and so the leaves are used in the most easy and effective way as a plug for the burrow. Often leaves are used to line the mouth of the burrow to a depth of several inches, possibly to protect the body of the worm from becoming unduly chilled by continual contact with the cold damp earth. Darwin describes

cases in which the needle-like leaves of the Scotch pine were used for this purpose; each pair of leaves was drawn in by its fused base and then the sharp tips of the separate leaves were pressed back into the earth, so that they should not hinder the free movement of the body. Worms often lie for many hours just inside the mouth of their open burrows, and they are apt to do this especially in the early morning hours, probably in order to enjoy the warmth of the sun; this habit leads to their detection and large destruction by birds. "It is the early bird that gets the worm."

Each burrow terminates usually in a little enlargement which is lined with tiny pebbles or hard seeds, and into this chamber the worm retires for the winter months or during any prolonged drought in the summer. Sometimes several worms remain coiled together during the winter.

Respiration. The need of a moist environment is a very real one to worms. It is absolutely essential that their skins should be kept damp, since there are no special respiratory organs, and the aeration of the blood takes place directly through the skin. There are two chief longitudinal blood-vessels, both of which can be seen through the transparent skin; the dorsal vessel runs the whole length of the body above the alimentary canal, and the ventral vessel below it. In each segment, two blood-vessels pass off from the ventral vessel, carrying impure blood to the skin, where it is oxygenated. The purified blood then flows through other vessels to the various organs of the body, and finally is carried to the dorsal vessel, in which it passes forward and is pumped by five pairs of short contractile vessels, lying on either side of the alimentary canal in segments 7 to 11, into the ventral vessel again, whence it is once more carried to the skin. The five pairs of contractile vessels are known as the five pairs of *hearts*.

The *blood* is red, containing haemoglobin, the substance present in the red blood-corpuscles of vertebrate animals; but in the worm it is not in special corpuscles, but is dissolved in the general fluid or serum of the blood, there being only white corpuscles floating in the red fluid.

It is the haemoglobin which holds the oxygen and carries it to the different parts of the body, and such an "oxygen-carrier" is specially essential to animals which may suffer

from a scarcity of oxygen in their environment, or which have small respiratory surfaces.

Senses. There are no special sense organs in worms. The only sense which is highly developed is that of *touch*, which is possessed by the whole surface of the body, so that the lightest touch, or any very small vibration of the soil, seems to be perceived by them. This is no doubt of advantage in warning them of the approach of such a ferocious enemy as a mole, although on the other hand it does not seem sufficient to cause them to withdraw deep into their burrows when a thrush alights on the ground near them.

A worm has no *eyes*, but all its front segments are specially sensitive to a change in illumination, this sensitiveness being shared to some extent by the whole body. That they have some sense of *taste* seems indicated by the preference they show for certain foods, *e.g.* onions and celery, and the ease with which they find such food suggests some sense of *smell*, although Darwin's experiments, in which he tested them with various strong-smelling substances such as paraffin and tobacco, prove that the sense is decidedly weak, at any rate for any odours that are strange to them. In the sense of *hearing* they seem entirely deficient.

Nervous System. The nervous system is much more highly organised here than in any Coelenterate. Radial symmetry has now given place to bilateral symmetry. We now have a creature with head and tail, with right and left sides, and correlated with this change of form we find the change from a radially symmetrical nervous system to one in which there is a centralised paired mass (ganglion) of nerve cells now known as the *brain*. This brain lies above the alimentary canal in the third segment of the body, and from it two short cords of nerve fibres pass down, one on either side of the oesophagus, the two uniting below to form a double ventral nerve cord which runs the whole length of the body below the alimentary canal, with a swelling in the middle of each segment. From this cord three pairs of lateral nerves arise in each segment.

Reproduction. Worms are hermaphrodite (see p. 30), but in them, as in hermaphrodite flowers, cross-fertilisation and not self-fertilisation is the rule.

After mating has taken place, each worm secretes from

the glands in the "clitellum" a quantity of mucus containing a horny substance which hardens on exposure to the air. Out of the ring so formed the worm slips backwards, depositing in it, as it does so, three or four eggs from the ovaries which communicate with the exterior by little pores in segment 14, and also a number of sperm cells which have been obtained previously from another individual, but temporarily stored in this worm in certain little receptacles in segments 9 and 10. With the ova and sperms is deposited some albuminous food-stuff on which the young worms will feed during their early development.

As soon as the body of the worm is withdrawn the two ends of the "cocoon" close, shutting in the contents. The cocoons are at first white, but soon turn yellow or brown. One end is rounded and the other usually somewhat drawn out (Fig. 43, *C*). Although there may be several eggs in the cocoon, only one, as a rule, completes its development, growing at the expense of the others. The little worm is perfect, though minute, when it makes its way out of the cocoon.

The Enemies of Worms. Most dangerous of the enemies of worms are those birds such as the thrush and blackbird, as well as many smaller birds, which pull the worms out of their burrows, and devour an enormous number of them. When venturing above ground, they constantly fall a prey also to hedgehogs, toads, frogs, lizards, and many other creatures who, living mainly on insects, have recourse at times to worms to supplement their otherwise somewhat unsubstantial diet. Some beetles, such as the "Devil's Coach-horse" (see p. 281), feed largely on them. Some centipedes, and the little carnivorous shell-bearing slug *Testacella*, follow and attack them underground, as does also the mole—the tiger of the underworld—a creature needing apparently a vast amount of food to enable it to live its extremely active life, and finding a large proportion of this food in the worms which inhabit the same strata of soil as itself.

Regeneration. In speaking of the dangers to which earthworms are exposed, it is interesting to note the very great power of regeneration of tissues and recovery from wounds that they possess. The loss of any number of segments from the back end of the body can be made good, the lost segments being regenerated from a special

tissue which arises at the cut surface. The new part can usually be easily detected by its paler colour and reduced diameter.

According to Kescheler,[1] the complete regeneration of the front segments on the hinder severed portion is more doubtful, though this may occur, at any rate in some cases when only four or five of the head segments are lost, even the oesophageal nerve ring and "brain" being then re-formed.

Action of Earthworms on the Soil.

The value of the effect of the activities of worms on the soil can hardly be overestimated. It is most important for plant life that the soil should be kept loose and open, so that it can be readily penetrated by the air, which is essential for the healthy growth of the roots, and also for the activity of the bacteria in the soil which prepare the food-salts in it for the plant.

Worms, by their burrows, which are constantly falling in and having to be replaced by new ones, loosen the earth and make it possible for air to enter even into hard soils. Their burrows also bring about a good drainage of the soil, preventing it from becoming too wet and heavy for vegetation. Further, by their habit of swallowing soil at different depths and then ejecting it in a finely divided state at the surface, they prepare it in an excellent way for the growth of young seedlings and shallow-rooted plants.

They add to the richness of the earth by dragging down leaves, which are then more rapidly decomposed than they would have been on the surface.

The work done by worms in bringing up the earth from the lower layers of soil and spreading it on the surface in the form of castings was studied in much detail by Charles Darwin, who gives in his book[2] a full account of the experiments he performed. It is well known that any layer of stones or lime left on the surface of a field in time becomes covered with a layer of rich dark earth, and Darwin examined special cases of this with the following results:—

(1) In a field of good pasture land, after nearly 15 years it was found that a layer of quicklime that had been spread over the surface was now nearly 4 inches below it. Mould of an average thickness of ·22 of an inch had been brought up annually by the worms.

[1] Kescheler, *Vierteljahrsschr. Nat. Gesellsch.* xlii., Zurich, 1897.

[2] *Vegetable Mould and Earthworms*, chap. iii.

(2) A piece of swampy waste land was drained and ploughed, covered with a layer of burnt marl and cinders, and sown with grass. After 21 years this layer was still distinguishable at a depth of 4 to 5 inches below the surface, the average annual increase of the surface layer being ·19 of an inch.

(3) In a chalky district where the chalk was overlaid with 6 to 14 feet of stiff red clay and this covered by a few inches of dark mould, a surface layer of broken chalk was added; after 29 years this layer was found 7 inches below the surface, mould having in this case also been thrown up at the rate of ·22 inch a year.

It is obvious that worms affect the surface of the land in two ways: they actually bring up soil as castings, and cover with it the objects on the surface; also they undermine the ground below any object with their burrows and so cause it to sink, so that there is an actual change in its level. In this way they have doubtless played a considerable part in causing the subsidence and burial of old Roman and other remains.[1]

The number of worms living below a given area of ground is very large. In garden soil, where they are specially numerous, it has been calculated that there are over 50,000 to an acre. In such a situation more than 10 tons of earth will pass through their bodies and be cast up at the surface in one year, and this in 10 years would form a layer of finely divided surface soil at least 2 inches deep. The formation of new surface soil by them does not, however, go on continuously at this rate, for since earthworms find their food chiefly in the richer surface soil, when they have burrowed in this and formed a layer of 7 to 12 inches thick of their castings, they will continue to burrow in the same soil, passing it over and over again through their bodies.

Worms also play some part in the breaking down of the rocks of the sub-soil, for, owing to the digestion of the leaves, acids similar to humic acids form in the intestine, pass out with the castings, and are washed down by the rain on to the rocks, disintegrating their surfaces.

In many ways, therefore, worms affect the surface of the earth, making it more suitable for the growth of plant-life, and thus rendering a service of great value to man. As Darwin

[1] *Op. cit.* chap. v.

says in his concluding paragraph: "When we behold a wide turf-covered expanse . . . it is a marvellous reflection that the whole of the superficial mould over any such expanse has passed, and will again pass, every few years, through the body of worms. The plough is one of the most ancient and most valuable of man's inventions; but long before he existed the land was in fact regularly ploughed and still continues to be thus ploughed by earthworms. It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organised creatures."

Tubifex. River-worms. River-worms, or Red-worms (*Tubifex rivulorum*), are thread-like aquatic forms, very common in shallow pools, streams, and rivers. The body is from 1 to 1½ inches long, and is bright red, owing to the transparency of the skin, which allows the blood-vessels and even the other internal organs to be clearly seen through it. They live in colonies in the soft mud below the water, and when undisturbed they will project their tails out of the mud, waving them about so that they form a red patch that quickly attracts attention; if alarmed they at once retreat into their mud burrows.

They breed very rapidly, and form a natural and excellent food for fish and other carnivorous aquatic creatures.

To keep them healthily in captivity, they must be given plenty of soft mud in which to burrow, and the water above them must not be more than 3 or 4 inches deep.

Earthworms and River-worms are Chaetopod Annelids, or Bristle-footed Ringed-worms, but there are other forms of the same class which differ from them in the greater complexity of their body-structure, though they still have the same characteristic bristles or chaetae. These are the marine worms which are described in the next chapter.

Practical Work on Earthworms

1. Earthworms should be kept in a "wormery," made of a box having one or two glass sides that can be covered or uncovered at will. This box should be about 12 inches deep; it should be filled with soils of markedly different appearance, in well-defined layers; the way in which the lower soils are brought up to the surface

can then be observed. The earth should be pressed very firmly together and kept slightly damp. Food of different kinds should be left on the surface of the soil, and the treatment of it by the worms watched. Some of the worms are sure to make their burrows against the glass sides of the box if these are kept covered, and the structure and position of them should be noted.

2. Dig up a few earthworms of different sizes and carefully examine them, verifying all the external characteristics mentioned in the preceding chapter. Feel the bristles and listen to the sound they make as the worm crawls over a piece of paper. Watch the movements of the body.

3. Look for worms in a garden at night by the light of a lantern. Try to find out what the worms are doing. Are they sensitive to the light? Test their sense of sound and of touch. Mark several burrows and visit them the next day; look for any that are plugged with leaves or stones and see how this is done. Try to trace one burrow down to its end.

4. Examine worm castings, and, in some place where worms are plentiful, from a measured small area of soil collect all the castings day by day for a month, in order to see how much is brought up. Examine the nature of the soil of the castings.

5. When digging, always look out for worm cocoons, and if found with eggs still within them, keep them carefully in *moist* soil until the young worms hatch out.

6. Read "The Work of Earthworms" in *The Biology of the Seasons*, by J. A. Thomson; also "Concerning Lawns and Earthworms" in *The Book of a Naturalist*, by W. H. Hudson. Nelson. 2s.)

CHAPTER VII

ANNELIDA (*continued*)

Class I.: CHAETOPODA (*continued*)

The Bristle-worms of the Sea.

THESE sea-worms differ from earthworms in several points, but resemble them in having the same type of segmented body, bearing bristles. Unlike earthworms, they have usually a distinct head, with eyes and feelers on it, and also well-marked breathing organs or gills, which project freely from their bodies, and which, in those genera which build round their bodies a hard tubular case, often form a conspicuous and beautiful frill, projecting at the free end of the tube. Further, the chaetae or bristles are in clusters, situated on definite stump-like projections of the body (parapodia) and forming, in the free-swimming worms, efficient little paddles. Because of this arrangement of the chaetae in clusters, these marine worms are called *Polychaeta*.

Free-swimming forms (Errantia). Many of the free-swimming sea-worms (*Errantia*) are common in rock pools or on the rocks left uncovered by the tide. These forms are predatory and have sharp jaw-like structures in their mouths. The Paddle-worm (*Phyllodoce lamelligera*) is one of these (Fig. 44). It is a beautiful iridescent green form, with a body usually 8 to 12 inches long, though it may be as much as 2 feet in length and half an inch across. It is commonly to be found lying under stones near low-tide mark. These worms are often called "leaf worms," because of the leaf-like paddles which develop on the bristle-stumps (parapodia), and form an overlapping row down each side of the body.

Aphrodite, the Sea Mouse, is also a free-swimming form, though it has too clumsy a shape to swim freely, but crawls

about at the bottom of deep muddy pools. It lives beyond low-tide mark but is sometimes thrown up into shallow water, and so is named after the Greek goddess concerning whom the legend runs that she was born of the waves. The sea-mouse is peculiar on account of the thick covering of long fine hairs over the upper side of its flattened oval body, which may be as much as 6 inches long, but is usually a good deal smaller. The whole body is generally covered with mud when it is picked up, but if it is washed in a clean pool, the very beautiful iridescence of the hairs and bristles will become apparent.

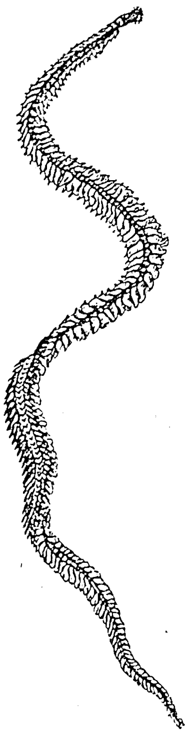

FIG. 44.—The Paddle-worm (*Phyllodoce lamelligera*). × ½.

Sedentary forms. (Sedentaria). A very large number of the sea-worms are not free-swimming but sedentary (*Sedentaria* or *Tubicolae*). For the protection of the body these worms form a tubular structure, which they either build up from the mud, sand, or shells around them, binding them together with a sticky substance exuded from their own bodies, or they make the whole tube of a calcareous matter which they themselves secrete (*e.g. Serpula*, Fig. 49). In a few cases they merely burrow in the sand and mud.

Arenicola. The Common Lugworm or Lob-worm (*Arenicola marina*), used so much by fishermen for bait, is one of these burrowing forms. It is 8 or more inches long, and its colour is black or brownish-green, partly due to the large quantity of dark-coloured mud that it swallows in burrowing and from which it extracts its food. At every low tide on nearly every sandy and muddy sea-coast the presence of these lugworms is indicated by the great number of castings or "sand-ropes" lying on the surface.

Terebella. *Terebella* is a case-building form. One species, the Sand Mason (*T. conchilega*), builds a little flexible tube of sand and pieces of shell, with a fringe of sandy threads

projecting from the upper end (Fig. 46); these may often be seen on a sandy shore above low-tide mark, the upper part only of the tube projecting vertically above the surrounding sand. It is interesting to watch these tubes being formed: the particles are seized by the delicate tentacles of the worm and passed into the mouth, where they are moistened by a secretion, and then placed in position at the margin of the tube by the

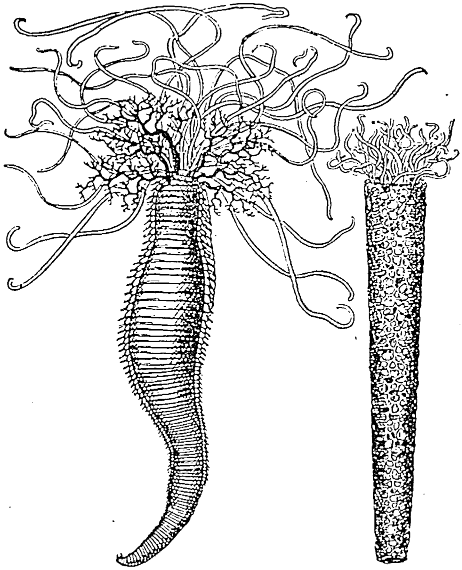

FIG. 45.—The Mud Mason (*Terebella* (=*Leprea*) *lapidaria*). $\times \frac{1}{3}$.

A, The worm retracted within the sandy case of a Pectinaria; *B*, worm removed from the case, showing the long tentacles, the three pairs of branched gills, and the parapodia (bristle-stumps) down each side of the body.

tentacles, helped by the lower lip of the worm. *Terebella* (*Leprea*) *lapidaria* forms mud tubes which lie horizontally under stones. The *Terebella* in Fig. 45 having been turned out of its own case, had taken up its abode temporarily in the tube of a *Pectinaria*, an unusual occurrence. In each species the body may be entirely withdrawn into the tube, but when undisturbed there project from it three pairs of bright-red branched gills, which are attached to some of the

anterior segments of the body, and also many of the long thread-like feelers or tentacles.

Pectinaria. The Comb-worm (*Pectinaria*) also builds a sandy case like that of *Terebella conchilega*, but smaller, neater, and more compact, and therefore not so flexible; also it has no marginal sandy fringe (Fig. 45, *A*). The worms themselves (Fig. 47) can be easily recognised by the two bunches of golden-coloured stift bristles lying one on each side of the head; the short tentacles lie outside these bristles, and

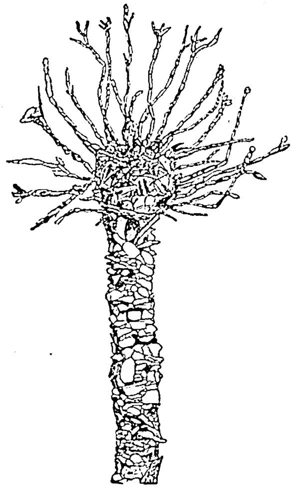

FIG. 46.—The upper end of the empty tube of *Terebella conchilega*. (From the *Cambridge Natural History*.)

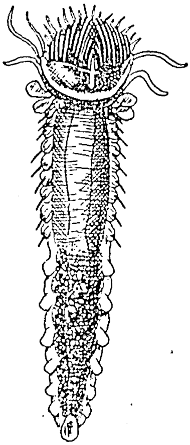

FIG. 47.—*Pectinaria* removed from its tube.

on either side below the head are two pairs of short bladder-like gills. The body ends in a little disc which closes the narrower end of the tube. By means of its bristles the worm burrows, head downwards, in the sand, the narrower end of the tube alone projecting above the surface.

Sabella. *Sabella* is a worm which builds a tube of mud. It is a social form, and clusters of the tubes of some species of *Sabella* often exist side by side, and, with the sand that gets washed in between them, cause the formation of such firm masses that they can only be removed with a hammer and chisel. The beautifully coloured gills are

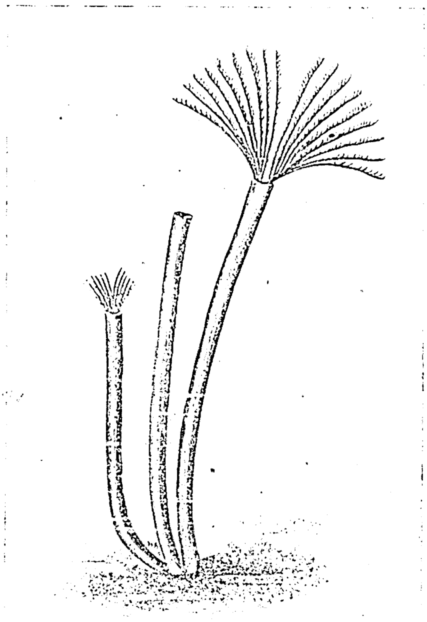

FIG. 48.—*Sabella* (*pavonina?*) in its mud tube (natural size).

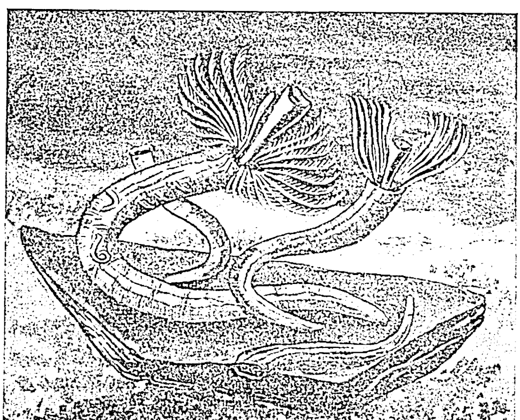

FIG. 49.—*Serpula vermicularis* (natural size).

arranged in the form of two spirally curved plates (Fig. 48). Between the bases of these two plates is the mouth.

Serpula. *Serpula* secretes its own tube, which is formed of a calcareous substance given out by the body; usually several of these white limy tubes are found together. These worms live in rather deep water, with the curved tubes attached to some rock at their lower ends, but with their upper, larger ends free. From the upper end project a pair of often brilliantly coloured, scarlet or blue, fan-like plates of gills, which are kept continually moving, driving a current of water, with the food it contains, into the mouth. When the

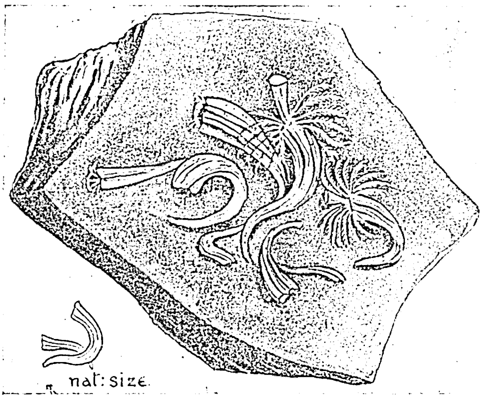

FIG. 50.—*Pomatoceros triqueter.*
Several attached to a rock (enlarged).

worm withdraws into its tube, the mouth of the tube is closed by a special club-like structure called the operculum (seen projecting between the gills in Fig. 49).

Pomatoceros. *Pomatoceros triqueter*, another very similar but smaller form which secretes a curved limy tube, is far more common than *Serpula*. It lives in shallow water between tide marks. The gills and operculum resemble those of *Serpula* (Fig. 50).

Spirorbis. *Spirorbis* is another common but very much smaller form; its little white spirally coiled tubes are very frequently found attached to bladderwrack seaweed and to the shells of other sea creatures (Fig. 51).

The sea-worms here mentioned are only a few representatives of the many to be found on our coasts. They have been chosen because they illustrate in some degree the variety of structure found amongst the Chaetopod worms and their powers of adaptation to different spheres of life. Earthworms are more or less protected by their underground habit, and since air is plentiful in their burrows and their skin is so thin as to be penetrable to it, they have no need of special respiratory organs. Sea-worms, on the other hand, living exposed to the attacks of many enemies and being in many cases sedentary, need a protective tube, and this necessitates special

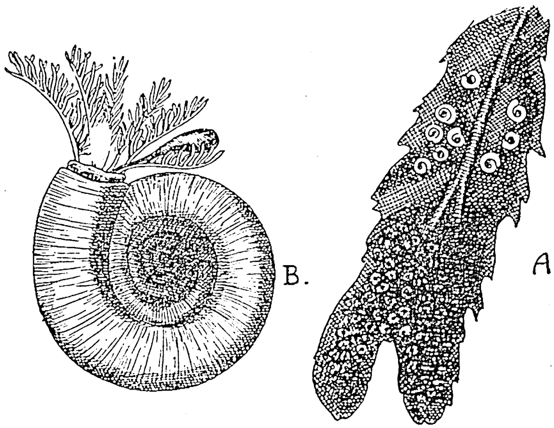

FIG. 51.—*Spirorbis borealis.*
A, Attached to seaweed (nat. size). *B*, One individual much enlarged.

respiratory gills which they can project beyond the tube, and in which the blood is oxygenated.

We are not accustomed perhaps to think of worms as things of beauty, and yet these sea-forms exhibit some of the most wonderful colours seen in the animal kingdom, and the study of them well repays both the artist and the naturalist.

Class II.: HIRUDINEA OR LEECHES

(RINGED WORMS DESTITUTE OF BRISTLES)

Leeches are usually water-inhabiting creatures, though they are found also in damp earth. They swim through the

water with an undulating motion of the flattened body, or move along the pond-bottom with a "looping" action, clinging to the ground with the suckers, of which there is one at each end of the body.

The Horse Leech (*Aulostomum* (*Haemopsis*) *gulo*) is common in most ponds; the body is 3 or 4 inches long and may be half an inch broad, being wider at the base than at the head end. It is a greenish-black colour on the back and lighter underneath.

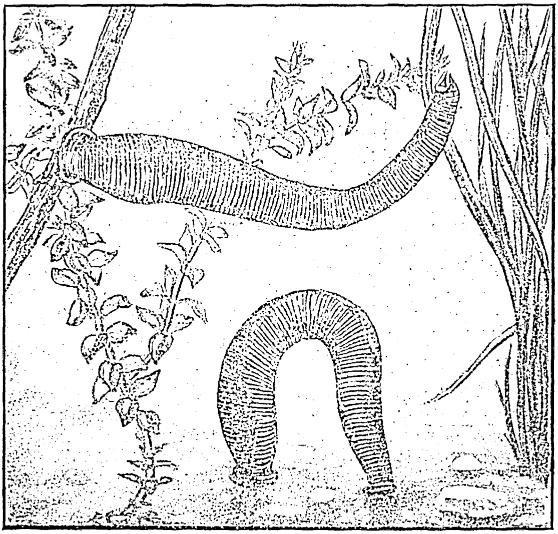

FIG. 52.—Horse Leeches in Water. (Life size.)

The Medicinal Leech (*Hirudo medicinalis*) is also of a greenish colour, but has three yellow bands running along each side of its upper surface. This species does not now occur in our ponds, and we only know those that are imported from the Continent.

Body Structure. The body in leeches is segmented; the rings, however, are sometimes very indistinct, each segment being subdivided by additional rings. At the hind end there is a large circular sucker which is used merely for adhesion, and there is also another sucker surrounding the mouth. Inside the mouth are three saw-like

jaws, with which the creature, having fixed itself by its mouth-sucker to an animal, makes a small wound; through this it can suck the blood of its victim, which may be almost any creature to which it can attach itself.

Reproduction. Leeches lay eggs which are surrounded by little transparent capsules, and are deposited on submerged water-weeds, or on the damp ground close to the water. The cocoon is formed in the same way as that of the earthworm, the two ends closing when the leech has slipped backwards out of it. The flattened greenish-brown capsules of the Small Pond Leech (*Nephelis vulgaris*) are common on the under side of the leaves of water-plants. They are to be found during the summer months, from June to August, and the eggs hatch out in about six weeks. This leech attacks snails.

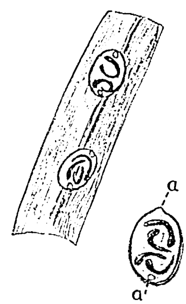

FIG. 53.—Egg Capsules of *Nephelis vulgaris*.

a, The marks where the capsule has closed.

Affinities of Worms. In the preceding two chapters only a few of the very many and varied forms of worms have been described, and yet much variety and adaptation has become apparent. The group is one of special interest to the student of evolution also, for it seems possible that in it we may find those forms that will indicate to us some of the first of those steps by which, from such a lowly grade of life, those modifications have arisen which have led to the evolution of the back-boned or vertebrate type now dominant on the earth.

At present the problem of the origin of the Vertebrates is quite unsolved, but when we come to consider their characteristics, we shall find they show a resemblance to Annelids in the segmentation to be traced in certain of the body tissues; and the view that these two groups had a common origin is tenable in spite of certain serious difficulties, such as the difference in the relative position of the alimentary canal and the main nerve cord of the body; in the Annelids, as we have seen, the latter runs on the ventral side of the body, whilst in Vertebrates it is dorsal.

A worm-like, burrowing creature, *Balanoglossus*, which has some striking points in common with certain of the lowest

vertebrates, used formerly to be considered as allied to true worms, but an investigation into its larval history has disclosed distinct affinities with the Echinoderms,[1] and suggests an ancestral link between this group and the Vertebrates. So the discussion of the vertebrate origin is further involved, for these two groups, with both of which it is possible the Vertebrates may have affinity, are in themselves strikingly dissimilar.

Classification of the Annelida mentioned in Chapters VI. and VII.

Class I. Chaetopoda.—Bristle-worms.

Sub-class 1. **Oligochaeta.**—Those with no definite "bristle-stumps" (parapodia), but only a few single bristles on each segment. No distinct head. Chiefly land or freshwater forms.

Lumbricus terrestris, The Earthworm.
Tubifex rivulorum, The River-worm.

Sub-class 2. **Polychaeta.**—Those with definite parapodia, each usually bearing many long bristles. A definite head is present, bearing eyes and tentacles. Special filamentous gills are often developed. Chiefly marine forms.

Phyllodoce, The Paddle-worm.
Aphrodite, The Sea-mouse.
Arenicola, The Lob-worm.
Terebella, The Mason-worm.
Pectinaria, The Comb-worm.
Sabella, *Serpula*, *Pomatoceros*, *Spirorbis* — All tube-forming, and peculiar in having distinct thoracic and abdominal regions in the body, marked by differences in the chaetae.

Class II. Hirudinea.—Leeches.

Hirudo medicinalis, The Medicinal Leech.
Aulostomum (*Haemopsis*) *gulo*, The Horse Leech.
Nephelis vulgaris, The Small Pond Leech.

Practical Notes on Sea-worms and Leeches

Polychaeta. Some of the marine bristle-worms are so beautiful and so easy to keep for a time, that they should be studied in the sea-water tank as well as in their natural habitat.

Sabella, *Terebella*, and *Pomatoceros* are fairly easily found in

[1] See page 75.

comparatively shallow water. *Serpula* inhabits deeper water, and dredging is usually necessary to obtain it.[1] All these forms flourish in captivity for a time, if supplied with plenty of the microscopic food on which they feed. To ensure this, seaweed, fresh from the sea, should be occasionally rinsed in the water of the tank. It is best of course to keep these forms in a tank at the seaside, so that they can be returned to their native haunts after they have been kept in captivity awhile.

Other Polychaets should be searched for in rock-pools. For the identification of specimens reference should be made to W. C. McIntosh's *British Annelids*, part ii., which deals fully with certain families of Marine Bristle-worms; also the *Cambridge Natural History*, vol. ii., should be consulted; and the *Plymouth Aquarium Guide* is most useful for beginners.

Hirudinea. *Horse Leeches* may be brought back from a pond and kept for a short time, but the freshwater aquarium in which they are put must be carefully covered, otherwise they will escape. There must be no other inmates of the tank, as the leeches will attack even fish.

[1] Beautiful specimens are obtainable from the Marine Biological Laboratory, Plymouth.

CHAPTER VIII

PHYLUM VI.: PLATYHELMINTHES OR FLAT-WORMS

FLAT-WORMS are small, rather worm-like creatures, with a soft, flattened, bilaterally symmetrical body, either unsegmented, or with segments as in the Cestoda (see p. 102).

In members of this group we find three body-layers well developed, but, unlike true worms, they have no body-cavity or coelom outside the alimentary canal or gut; the mesoderm forms a kind of connective tissue entirely filling the space between the gut and the skin.

Microscopic examination of stained preparations of the body reveals a fairly complex structure, with a specially peculiar excretory vascular system.[1]

Turbellaria or Whirl-worms. The best-known Flat-worms are the *Turbellaria* or "Whirl-worms," little forms never exceeding an inch in length, and often much smaller than this, which crawl over the ground like slugs, or swim by the whirling motion of the cilia which cover their bodies. Such whirl-worms are found both in sea-pools and in ponds, where they are useful as scavengers, for they feed on dead animal matter. They have a much-branched digestive system, with three main branches to the gut in the freshwater forms, but more in many marine species. The alimentary canal is peculiar in having no anus.

The commonest marine form is *Leptoplana tremellaris* (Fig. 54), which is to be found under stones or seaweed when the tide is out. It has a flat, semi-transparent body, $\frac{1}{2}$ to 1 inch in length, which can either glide quickly over a surface, or swim freely in the water with a wave-like up-and-down motion.

[1] See *Cambridge Natural History*, 1896, vol. ii. pp. 25 and 41.

The only conspicuous structures to be seen on the upper surface of the live creature, even with the aid of a strong lens, are: the four groups of minute dark eye-spots, between these a clear oval body which is the brain, and, running longitudinally down the body, an irregular, sometimes broken, streak; this streak is the central part of the digestive system, from which many branches run out to the circumference of the body. The cilia which cover the body can only be seen under a high magnifying power; by their constant movement they cause little whirlpools in the surrounding water. *Leptoplana* is carnivorous; its mouth is situated in about the centre of the under side of the body, and through it the large funnel-like pharynx (throat) can be protruded, discharging a digestive juice over the tissues of the body of its prey. The creatures are hermaphrodite but cross-fertilised. The eggs are laid in the spring or summer, and hatch in a few weeks. *Leptoplana* is an example of the "polyclad" Turbellarians, all of which are marine forms with many lateral branches to the stomach.

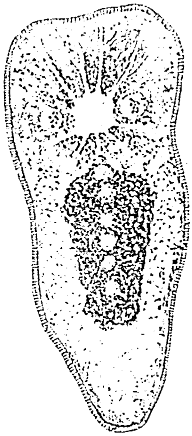

FIG. 54.—*Leptoplana tremellaris.* × 3. (Upper surface.)

Planaria lactea is an equally common Turbellarian, but found in fresh water; it is a "triclad" Turbellarian, *i.e.* one with only three main branches to the stomach (see Fig. 55). Like *Leptoplana*, it glides along, but it may move also with a looping motion, fixing the front end of its body by means of a sucker on the lower surface of the head, and then drawing the body up behind. It is about $\frac{3}{4}$ of an inch long.

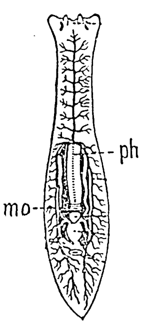

FIG. 55.—*Planaria lactea.* (Diagrammatic. × 2.) (From the *Cambridge Natural History*, vol. ii.)

ph, Pharynx or gullet; *mo*, mouth.

Mesostoma ehrenbergii, another leaf-like Turbellarian common in ponds, is a type of those with a straight, rod-like

alimentary canal. Its oval body is about half an inch long, and is pointed at both ends. It lives in the water, gliding over the water-weeds in search of the small worms and insect larvae on which it feeds.

Trematoda. Liver-flukes. The *Trematoda* are Flat-worms which, unlike Turbellaria, are parasitic, and are not usually ciliated. The body is provided with suckers with which the Trematod clings to its prey. The Liver-fluke of the sheep (*Distomum hepaticum*) is one of these. It has an extraordinary life-history, living part of its life within the body of a water-snail (*Limnaea truncatula*) or of a land-snail (*Helix*), and the other part inside the liver of a sheep. It passes out from the snail on to the grass, and is then swallowed by the sheep when it eats the grass.[1]

Cestoda. Tape-worms. The Tape-worms are also parasitic; they have usually a long ribbon-like, segmented body with no alimentary canal and a rounded head bearing suckers or hooks for adhesion to their host. Each segment is capable of reproduction, and separates from the rest when ripe, leaving the body of its host, and passing the second stage of its life in another host.

Taenia solium, the tape-worm parasitic in man, passes the second stage of its life in the pig as the "bladder-worm," and then again infects man if the pig's flesh is eaten without having been previously cooked sufficiently to kill the bladder-worms.[1]

Nemertinea. Ribbon-worms. The Nemertine worms are long, soft-bodied, unsegmented forms, probably nearly related to the whirl-worms. Like them, they have no body-cavity, and they have a covering of fine cilia, but in some other ways they are more highly developed; specially characteristic of them is the long muscular proboscis which can be protruded from the front end of the body just above the mouth. It has, however, no connection with the mouth, but seems to be a special organ of touch and perhaps also a weapon, since in some cases it carries a sharp spine, though not in the genus *Lineus* mentioned below. The alimentary canal, unlike that of Turbellaria, ends in an anus.

A well-known marine member of this class is the curious *Lineus marinus*, the Sea Long-worm or Sea Snake, which, it is

[1] For full life-history see Parker and Haswell's *Zoology*, pp. 226-37.

said, may even grow to a length of 100 feet. It is, perhaps, the longest animal known.

Lineus is found in rock-pools near low tide mark; its body is about as thick as a boot-lace, and it twists it in and out into complicated knots (Fig. 56). In spite of its ability to twist in this way, the body is very brittle, and it is therefore difficult to handle without injuring it, though if successfully transferred to a sea-water tank it will thrive, and its velvety-looking body with changing purplish hues will be a beautiful object. The front end of the body is blunt. Sometimes there may be seen protruding from it a long fine thread; this is the characteristic proboscis with which it is said to lasso its victims—chiefly marine worms—drawing them to its mouth, and swallowing them whole.

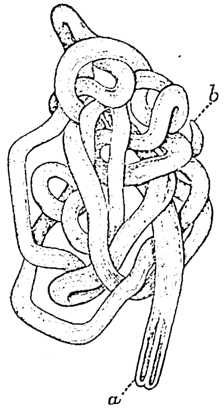

FIG. 56.—*Lineus marinus.* (From the *Cambridge Natural History.*)

a, Anterior end; *b*, posterior end.

PHYLUM VII.: NEMATODA, THE ROUND OR THREAD-WORMS

These "worms" have a long, thin, unsegmented body, round in section, and with a muscular body-wall, thicker than that in Flat-worms.

A body-cavity is present, and this too marks them off from Flat-worms, which have no body-cavity. They are usually small forms, though some reach the length of 5 or 6 feet. They move with a wriggling motion. Most of them are parasitic.

Ascaris lumbricoides is a common round-worm, parasitic in the intestine of man; it may be nearly 16 inches long.

Trichina spiralis is another parasite, at first living in the intestine of man, and then in his muscles, causing the disease known as "trichiniasis." In another phase of its life-history it is parasitic in pig, producing what is known as "measly" pork.

Many other Nematodes attack valuable domesticated animals, so that on the whole they are a class distinctly hostile to the welfare of man.

A large number, however, are non-parasitic, living in damp earth or decaying matter. Some, such as the "vinegar eels" and "paste eels," have a wonderful power of withstanding desiccation, so that they may be wafted about in the air—a fact that explains their apparently mysterious appearances at times in weak vinegar or sour paste.

PHYLUM VIII.: POLYZOA,[1] SEA-MATS OR CORALLINES

These Polyzoans are nearly all marine colonial forms, and many of them are common well-known objects of the seashore. They are often mistakenly called Zoophytes, though they are far removed from the true Coelenterate zoophytes (see p. 23).

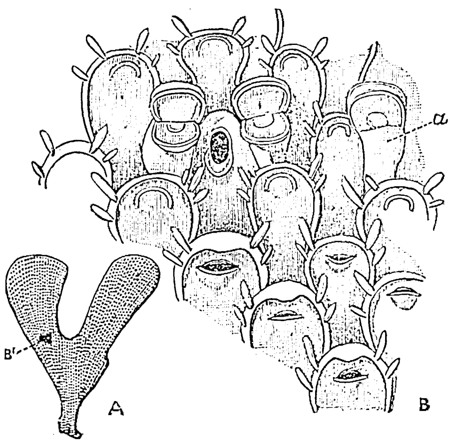

FIG. 57.—The Sea-mat (*Flustra foliacea*). (From the *Cambridge Natural History.*)
A, Natural size, *B'* indicating the portion magnified in *B*; *a*, zooecium with closed lid.

Flustra, the Sea-mat.

Perhaps the commonest and best known is the sea-mat (*Flustra*), which is thrown up after every storm on some parts of our coast, and soon looks like a dry brown seaweed. If obtained when first cast up, before it has dried, and then examined in sea-water under the microscope, it will be found to consist of a colony of individuals. Each has secreted round itself a horny substance, which has hardened into a little oblong cell, or "zooecium," decorated at each side with short spines and having an opening at the upper end covered by a little hinged lid. After a time, the tentacles of the creatures within may be seen gradually pushing up the lid. The polyps are arranged in two layers, back to back; so whichever surface of the "mat" we look at, we get the same view of them.

[1] See Note on page 4.

The tentacles are numerous, and are united at their base to form a funnel-like structure at the bottom of which is the mouth. A careful study of such Polyzoans has revealed that within each zooecium is a lining of living cells, and within this a body-cavity (a true coelom) containing a U-shaped alimentary canal, the anus opening close to the mouth of the zooecium (cp. *Bugula*, Fig. 58). A rudimentary nervous system is present, but no vascular system. In *Flustra* there are no definite excretory organs, but these occur in some Polyzoa.

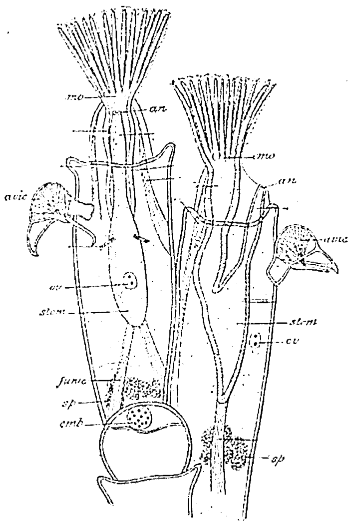

FIG. 58.—The Bird's-Head Coralline (*Bugula avicularia*). Two zooids much magnified. (From Parker and Haswell.)

an, Anus; *avic*, avicularia; *emb*, an embryo; *funic*, funiculus; *mo*, mouth; *stom*, stomach; *ov*, ovary; *sp*, spermary.

Other Polyzoa.

Another very similar form is *Flustrella hispida*, but this only occurs as encrustations, frequently on the seaweed *Fucus*.

Membranipora is another genus which makes a whitish lace-like encrustation on *Laminaria*.

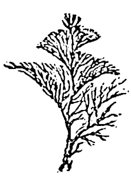

FIG. 59. — *Bugula turbinata*, a small colony, natural size. (From the *Cambridge Natural History*.)

In *Bugula avicularia*, the common Bird's-Head Coralline, the colony has a tree-like form, and may be several inches high. It forms brownish or purple tufts on rocks or pieces of wood in the sea. *Bugula turbinata* has a spiral form (Fig. 59).

In this genus, each zooecium has attached to it a curious little body, very like a bird's head, called an "avicularium." The "beak" of this structure is constantly moving, the two parts of it opening and shutting again with a snap (Fig. 58).

Rejuvenation.

A curious feature in the life-history of these Polyzoa is the way in which at times the central

organs in the body seem to disintegrate, forming a conspicuous "brown body" inside the zooecium, after which process, from the still active body-wall, new organs are formed, so that the "brown body" may come to lie within the stomach of the rejuvenated individual, and finally it may pass out of the anus. This "brown body" is a conspicuous object, which is sure to be observed by any student of Polyzoa; it may be connected with the excretion of waste matter.

Reproduction. The individual zooids are hermaphrodite in most Polyzoa. The reproductive organs are formed either from the body-wall, or from a cord of tissue called the *funicle* (Fig. 58, *funic*), which stretches from the stomach to the body-wall. The eggs often develop for some time within a special pouch of the zooecium (Fig. 58, *emb*).

Freshwater Polyzoa. In some freshwater colonial forms, such as the free-moving *Cristatella*, which dies in the winter, special structures known as *statoblasts* are formed; these persist after the death of the individual zooids, and give rise to new colonies in the spring. Such statoblasts consist of small buds, formed from the funicle; they become enclosed in two horny concave shells, which are kept tightly closed and serve as an efficient protection in the winter. These freshwater forms are further characterised by the tentacles being arranged in a horse-shoe curve, instead of in a row, as in the marine Polyzoa.

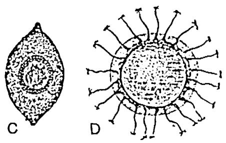

FIG. 60.—Statoblasts of Polyzoa. (From the *Cambridge Natural History*.)

C, Lophopus crystallinus; D, Cristatella mucedo.

The oval colony of *Cristatella* may be over two inches long (Fig. 61). It creeps along on its flat under surface, whilst the zooids project from the upper convex surface of the greenish jelly-like mass. It is found in shallow still water, creeping over the stones or weeds in sunny spots. The statoblast of *Cristatella* is peculiar because of the hooked spines which surround it (Fig. 60).

Lophopus is another, but smaller, freshwater colony, which may be found on duckweed, looking like a little speck of jelly until it expands its beautiful horse-shoe of tentacles (Fig. 62). It also can move, though but slowly, over the surface on which it lives. The statoblasts are shown in Fig. 60.

Plumatella forms branching, thread-like colonies, adherent,

in the case of the common *P. repens*, to the leaves of water-plants (Fig. 63).

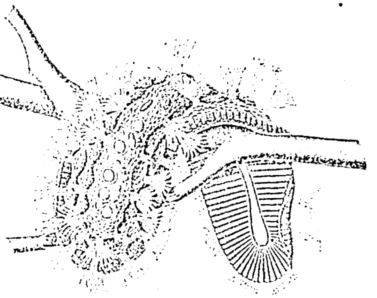

FIG. 61.—*Cristatella mucedo.* Entire Colony (natural size). (After Allman, from Parker and Haswell.)

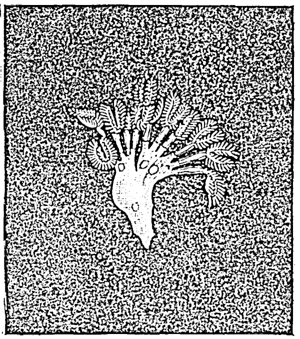

FIG. 62.—*Lophopus crystallinus*, whole colony (× 2). (From the *Cambridge Natural History.*)

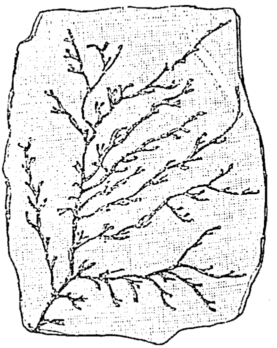

FIG. 63.—*Plumatella repens*, on a piece of water-lily leaf (nat. size). (From the *Cambridge Natural History.*)

PHYLUM IX.: ROTIFERA

WHEEL ANIMALCULES

Rotifers are microscopic but multicellular forms, very abundant in ponds and ditches. The general appearance of four of them is shown in Fig. 64.

They are bilaterally symmetrical, and each has a curious ciliated disc on the head, and, at the opposite end of the body, a tail or "foot" which is often jointed, and is more or less retractile. Sometimes this foot is forked, or divided into

three processes or "toes"; through the tips of these is discharged the secretion from certain "cement" glands in the tail,

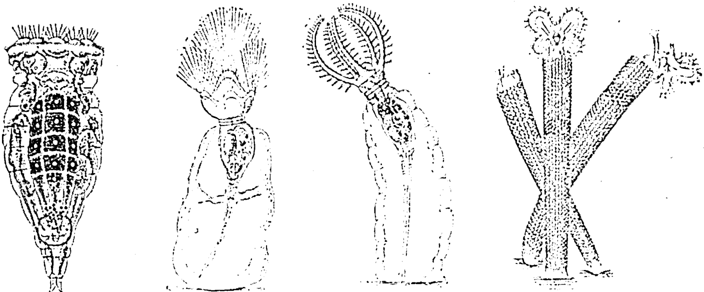

FIG. 64.—Typical Rotifera. (After Hudson and Gosse.)
(The actual size is microscopic.)

by means of which the animal is able to fix itself temporarily to any support in the water. Some few Rotifers are permanently fixed, and in such cases the body is usually surrounded by a tube; this may be transparent, being secreted by the skin of the Rotifer (*e.g.* in *Floscularia* and *Stephanoceros*), or it may be made of foreign particles which are built up into a case by the creature itself (*e.g. Melicerta*). Most Rotifers, however, can swim freely in the water by the movements of the cilia of the disc (*e.g. Hydatina*), and some also creep about somewhat like a Looper Caterpillar. A few have stiff, hair-like appendages which can be vigorously moved, causing a skipping movement (*e.g. Pedalion*, Fig. 65).

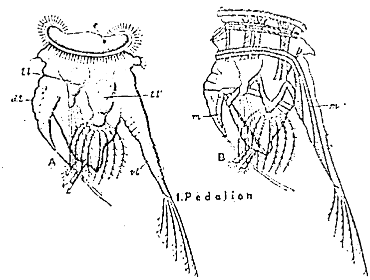

FIG. 65.—The Skipping Rotifer (*Pedalion*). (After Hudson and Gosse.)
A shows the outer form; *e*, eye-spot; *dl*, dorsal limit; *vl*, ventral limit; *ll-il'*, lateral limbs. *B*, Diagrammatic to show the muscles, *m*. (The actual size is microscopic.)

Though these forms are all microscopic, they are complicated in internal structure, for they have a body-cavity (coelom) distinct from the alimentary canal, and also excretory,

reproductive, and nervous systems, the brain being relatively large, though the sense organs are very simple.

Most of them live in fresh water, though a few are marine, and most of them live free independent lives, though a few are parasitic, as *e.g. Notommata Werneckii*, which is not infrequently met with inside the filaments of the freshwater Alga, *Vaucheria*, where it forms gall-like swellings.

In the summer these Rotifers usually lay parthenogenetic eggs of two sizes, the larger eggs giving rise to females and the smaller to males. Before the winter they also lay thick-shelled winter resting eggs, which develop in the following spring. These eggs have probably been fertilised. The adult active individuals have but short lives. In the case of *Hydatina*, which has been carefully investigated, the longest life seems to last not more than thirteen days.

Classification of the Worms mentioned in Chapter VIII.

Phylum VI. Platyhelminthes (Flat-worms).
- Class I. Turbellaria (Whirl-worms).
  - Order 1. Polycladida (marine forms with many lateral branches to stomach). *Leptoplana.*
  - Order 2. Tricladida (those with only three main branches to the stomach). *Planaria.*
  - Order 3. Rhabdocoelida (those with a straight, rod-like alimentary canal). *Mesostoma.*
- Class II. Trematoda (Liver-flukes).
  - *Distomum hepaticum.*
- Class III. Cestoda (Tape-worms).
  - *Taenia solium.*
- Class IV. Nemertinea[1] (Ribbon-worms).
  - *Lineus marinus*, the Sea-snake.

Phylum VII. Nematoda (Round or Thread-worms).
- *Ascaris lumbricoides.*
- *Trichina spiralis.*

Phylum VIII. Polyzoa (Sea-mats or Corallines).
- Marine forms.—*Flustra, Flustrella, Membranipora, Bugula.*
- Freshwater forms.—*Cristatella, Lophopus, Plumatella.*

Phylum IX. Rotifera (Wheel animalcules).
- *Floscularia, Stephanoceros, Melicerta, Hydatina, Pedalion, Notommata.*

[1] Nemertinea is now usually considered a separate Phylum. The classification here followed is that given in *A Text Book of Zoology*, by T. J. Parker and W. A. Haswell, 1910.

Practical Notes on Flat-worms, Polyzoa, and Rotifera.

1. *Turbellarian Flat-worms* may be found at all times of the year gliding over the water-weeds or the stones at the bottom of pond or sea. They are useful to keep in a tank with other creatures, as they act as scavengers, feeding on dead animal matter. The largest of them is *Planaria lactea*, which may be an inch long. *Leptoplana* [1] is common in shallow sea-water.

Nemertines may be found in rock-pools between tide-marks, usually hidden under stones; they may be identified by reference to W. C. McIntosh's *British Annelids*, part i. (published by the Ray Society).

2. *Polyzoa* may be looked for on submerged objects in shallow fresh water, or on the under surfaces of floating weeds, where *Plumatella*, *Lophopus* or *Cristatella* may be found. Any jelly-like mass not at once recognisable as the egg-mass of some insect or snail should be removed to a jar of clear water and left undisturbed for a time, when, if it be a Polyzoan colony, the beautiful horseshoe-shaped cluster of tentacles will soon be protruded from the polyps. *Statoblasts* may be found in the autumn floating on the surface of the water. The common marine forms are stiffer, for instead of the cuticle being gelatinous, as in the freshwater forms, it is horny or calcareous. *Flustra*, the Sea-mat, should be searched for on the sea-shore after stormy weather; the bladderwrack and other large seaweeds should be examined for the Polyzoans which may form encrustations on them—*Flustrella* and *Membranipora* are common.

Any specimens found may be identified by reference to *British Marine Polyzoa*, by T. Hincks, or *British Zoophytes*, by A. S. Pennington.

In all cases the marine specimens should be put into clean sea water and examined first under a lens; if the polyps are alive a compound microscope should be used, if possible, for the further investigation of their structure.

3. *Rotifers* are very common in stagnant fresh water, and a few are marine. Any that are found should be sketched, and identified by reference to *The Rotifera*, by Hudson and Gosse.

A full account of the Flat-worms, Round-worms, Polyzoa, and Rotifers will be found in the *Cambridge Natural History*, vol. ii.

[1] Specimens are obtainable from the Plymouth Marine Biological Station.

CHAPTER IX

PHYLUM X.: MOLLUSCA

General Characteristics. MOLLUSCA are all soft-bodied animals, usually covered by a continuous calcareous shell; this is secreted by a special fold of the body-wall, which lines the shell and which is called the *mantle*. This mantle may cover the whole body in one single piece, or it may hang down on the two sides of the body as two separate flaps or mantle-lobes. These two different conditions of the mantle are correlated with corresponding differences in the form of the shell, which may therefore be univalve or bivalve —a characteristic which may be used as a basis for the classification of the Molluscs, for many other peculiar features are associated with it.

The organ of locomotion in all Molluscs is a single, ventrally placed, muscular mass known as the *foot,* in the upper part of which the viscera are to some extent imbedded. As in all animals higher than the Coelenterata, there is an alimentary canal distinct from the body-cavity or coelom, but the latter is much reduced, being represented by the small "pericardium," or chamber in which the heart lies.

Members of the Phylum. The *Univalve Molluscs* (Class I., *Gastropoda*) include snails, slugs, whelks, limpets, periwinkle, etc.

The *Bivalve Molluscs* (Class II., *Pelecypoda*) include mussels, oysters, cockles, scallops, etc.

The *Head-footed Molluscs* (Class III., *Cephalopoda*) include the cuttlefish, octopus, nautilus, and others adapted to a free-swimming marine life.

Class I.: GASTROPODA[1]

(Univalve Molluscs)

Type: The Common Pond Snail (*Limnaea stagnalis*).

Habitat. The snail *Limnaea stagnalis* is to be found in almost any pond or river, especially where vegetation is thick. It is very hardy and can be easily kept in a tank, the only drawback to it being that it has such an omnivorous and hearty appetite that it is apt to destroy the plants rather too rapidly, and only common weeds should be kept with it. The Canadian water-weed *Anacharis* (*Elodea*) *canadensis*, which can always be easily obtained, is excellent food for it, and also the microscopic green algal growths which so often cover the sides of a tank. If trained to feed on these, the snail will do valuable work in an aquarium in keeping the glass free from these Algae which obscure the view.

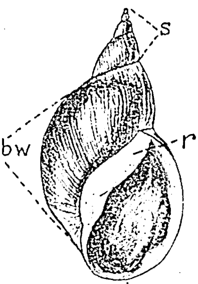

Fig. 66.—Shell of *Limnaea stagnalis*, seen from below.

s, Spire; *bw*, body whorl; *r*, reflected lip of the shell.

Method of Observation. The snails should be watched in ponds and large tanks, and also more detailed observations should be made on a couple of snails kept for a time in a small glass bowl or jar which can be easily handled so that the snail may be seen from all sides.

General Structure. The Shell. The soft body is covered by a shell which is conical in shape, but formed of six or seven spirally twisted coils or whorls. The first whorl is so small as to be a mere dot, but each successive whorl is larger, and is in close contact with the whorl before. The seventh or last whorl is bigger than all the others put together, and this is called the *body whorl*, all the rest of the shell forming the *spire*; the free edge of the body whorl is known as the *lip*.

If the shell is viewed from a point vertically above the apex of the spire, the whorls are seen to descend in a right-handed spiral; hence it is termed "dextral." (When the spiral turns to the left a shell is called "sinistral.")

On the body whorl many delicate lines can be seen parallel to the lip, and at intervals a few more deeply marked lines

[1] Greek, *gastero*, stomach; *pous*, *podos*, a foot.

occur. These are due to its discontinuous method of growth. The shell is frequently added to at its free margin, but the shell substance formed during one period of growth differs slightly from that formed at another; consequently fine lines of demarcation divide the different short periods of growth during one season. The more conspicuous lines usually indicate the limit between the growth of successive years.

The newly-formed shell is a light yellow-brown, but it very soon becomes discoloured and dark, in ordinary stagnant water. In texture it is rather delicate and brittle, and it is considerably rougher and darker on the outer side than on the inner, where it is lined with a light-coloured, smooth, glistening layer. A striking difference between the outer covering of the shell and the inner layer can be demonstrated in a perfect shell, by touching each part in turn with a rod dipped in weak hydrochloric acid (10 per cent or weaker). The inner lining shows an immediate effervescence, indicating that it is calcareous in composition, whilst the outer covering gives no such reaction.

If left immersed in acid for a sufficient time the whole of the shell will be dissolved away, except for the delicate outer skin, which will still retain the shape of the shell. This outer skin consists of a horny substance, similar to the chitin which forms the armour-like covering of most insects. It is of special value to snails, living as they often do in stagnant water, where there is abundant animal and vegetable life and much decaying organic matter, for such water contains a considerable amount of carbonic acid which, were it not for this protective layer, would attack the calcareous shell.

The size of the full-grown shell seems to depend chiefly upon the volume of the water in which it has grown; the less the amount of water the smaller the shell, other conditions being similar and favourable to growth.

By the coiling of successive whorls of the shell, each whorl is in contact with the one above it, but their inner margins do not touch, and so a hollow pillar is formed from apex to base of shell. This pillar is known as the *columella* of the shell, and the lower, open end of the cavity of the pillar is the *umbilicus*.[1] In *Limnaea*, however, the umbilicus is hidden by the lip of the shell growing over it (see Fig. 66).

[1] See diagram of the shell of the land snail, p. 138.

Sometimes, as in the whelk, the columella is *solid*, and so there is no umbilicus. To the columella are fastened the muscles which attach the snail to its shell, and also the upper end of the muscles which move the foot and cause its contraction and withdrawal into the shell when desired.

An examination of a section of the shell under the microscope shows that it consists of the following three distinct layers:—

(1) The thin, outer, horny layer mentioned above.

(2) A thick, calcareous, opaque layer, formed of many densely packed prisms of calcium carbonate, lying across the thickness of the shell. This is known as the prismatic layer.

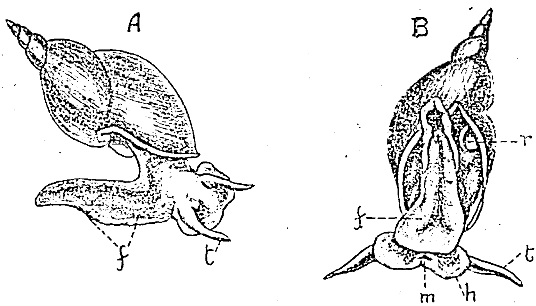

FIG. 67.—The Common Pond Snail (*Limnaea stagnalis*).

A, Seen from the right side. *B*, Seen from below. *t*, Tentacle ; *f*, foot ; *h*, head ; *m*, mouth ; *r*, respiratory aperture.

(3) An inner pearly or "nacreous" layer, usually much thinner than the prismatic layer, and formed of a number of very thin calcareous layers lying one over the other.

Body Structure (external). The shell protects the soft body of the snail, which may be entirely withdrawn within it or partly protruded beyond.

The most conspicuous structure when the snail is fully extended is the broad, flat muscular *foot* on which the snail moves, with a smooth gliding motion, over any flat surface, always keeping the sole in close contact with the surface, but moving forward by a series of alternate expansions and contractions of the muscles of the foot which travel through it with a wave-like motion.

Projecting above the foot in front, but attached to it

behind, is the *head*, a mere fleshy lobe, slightly indented in front, but bearing on its under side the *mouth*, and on its upper side a single pair of triangular "feelers" or *tentacles*. Just at the base of these, on the inner front side, is a pair of simple speck-like eyes, very slightly raised on little fleshy tubercles.[1]

Visceral Hump. The head and foot, after fusion, are continued as the *neck*, which passes up under the shell and is lost to sight. The body continues right up to the very top of the spire of the shell, following its coils; this upper part of the body is known as the *visceral hump*, for in it are contained the viscera—the intestine, kidney, heart, liver, and reproductive organ; the latter produces both egg cells and sperms, for this snail, like the earthworm, is hermaphrodite. (Most snails, but not all, are alike in this characteristic.)

Mantle and Shell Formation. The visceral hump is covered with a thin integument or skin. In the body whorl a fold of this integument grows down round the body, loosely covering it. This fold, which is known as the *mantle*, adheres closely to the inner surface of the shell, and terminates at its open margin in a thickened rim known as the *collar*. The "collar" is glandular, and from its secretions are formed the outer horny and the middle calcareous layers of the shell, whilst the inner nacreous or pearly layer is formed by secretion from any part of the surface of the mantle. If therefore the shell is damaged at its free edge it can be completely repaired, all three layers being renewed, but if part of the shell is removed higher up, the hole can be filled by the formation of fresh nacreous matter alone.

Mantle Cavity and Respiration. There is a space between the mantle and the dorsal wall of the body, known as the *mantle cavity*, but the communication of this space with the exterior is narrowed down to a small, round, tubular aperture (see Fig. 67, *r*) by the partial fusion of the collar with the body. The aperture lies on the right side of the body in *Limnaea*. This mantle cavity is filled with air, and functions as a respiratory organ or lung, the mantle which forms the roof and sides of the cavity being richly supplied with blood-vessels, to which is brought all the impure venous blood of the body. Here it comes into close contact with the air in the mantle chamber, and the blood is aerated and then

[1] For the structure of this eye see p. 134.

carried by a special vessel to the heart, whence it is again distributed to all parts of the body.[1]

To renew the air in this lung, the snail has to come frequently to the surface of the water; turning over, so as to bring the respiratory aperture just to the surface, it opens it with a little audible pop, and then causes the expulsion of the impure air and inrush of fresh air, by the alternate raising and flattening of the floor of the chamber, which is formed of the muscular dorsal wall of the body. The aperture may be kept open for a minute or two, but is always closed again before the snail descends in the water.

Movements. The usual method of movement of a snail is the slow gliding motion over a surface described above, but the "lung" is sometimes made use of to cause rapid descent in the water when the snail is irritated. Normally, when the lung is full of air, the snail floats in the water, shell uppermost, but the air may be suddenly expelled with force from the mantle chamber, owing largely to the sudden withdrawal of the body into the shell and the consequent upward pressure on the floor of the cavity; when this occurs the body sinks rapidly to the bottom of the water. After such a movement, the snail has soon to come to the surface again to breathe, climbing laboriously up a plant or the sides of the tank in which it is living. It will then frequently move across the surface of the water with its shell hanging downwards, and with the margin of the sole of the foot on a level with the water, the rest of its surface being slightly depressed. It is supported in this position by the tension between the margin of the foot and the surface film in the water.

When the snail is low down in the tank it can, if its lung is full of air, rise rapidly to the surface, merely by letting go of the plant to which it is clinging. This is an advantage in enabling it to stay below whilst feeding, until the need for fresh air is urgent, when it can in this way rise very rapidly to the surface to renew its supply.

Some species of *Limnaea* have been observed to aid their motion vertically in the water by forming, from a mucous secretion of the foot, a delicate rope of mucus, up and down which they travel. This "rope" may be fastened at first to some plant or stone in the water, then stretched out as

[1] For similar lung chamber in the garden snail see p. 135, Fig. 90.

the snail floats up, and again attached at the surface; or, in the case of other genera of snails which are heavier than water, and which therefore cannot rise in this way, the mucus is attached first to the top of some object, or even merely to the surface film of the water, and then drawn out as the snail sinks to the bottom, and fastened there, forming a convenient, short, and rapid means of rising to the surface when air is needed. We see, then, that although the snail has only one, very slightly specialised organ of locomotion, it is able to move in several different ways, and—by its rapid vertical rising or sinking in the water—to escape some of the dangers resulting from its aquatic life.

Mouth and Method of Feeding. These snails will eat almost any water-weed, and, failing anything else, they will scour the glass of the tank in which they are living in order to get any microscopic plants that may be adhering to it.[1] When doing this, the action of the mouth and tongue can be well observed.

The mouth is bounded by the soft upper and lower lips, the lower lip being deeply cleft, so that the boundary of the lips forms a T-shaped mark when closed. Set in these lips are horny jaws, one in the upper lip, and also a small lateral jaw in each lobe of the lower lip. Within the mouth there is a remarkable tongue or rasp (radula) which is the main organ used in obtaining food. This rasp is a strap-shaped horny structure, attached throughout its whole length to the floor of the mouth. The floor is very uneven, for there is a projecting cushion near the mouth supported by a little mass of cartilage, and behind this cushion a deep cavity, into which the rasp is continued (see Fig. 68). Down the whole length of the rasp are transverse rows of sharply-pointed curved teeth. *Limnaea* has sixteen teeth in each row, and over 500 rows.

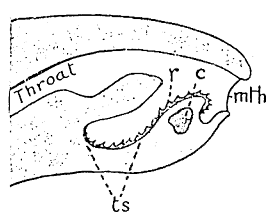

FIG. 68.—Longitudinal median section through the head of a Pond Snail. (Diagrammatic.)
mth, mouth; *r*, radula; *c*, cartilage; *ts*, tongue sac.

The number and shape of the teeth in each row vary in each

[1] They are said to like animal food also, and even to attack live animals occasionally, but I have never observed this in those I have kept.

genus of snail; the variety of the teeth in one row of the radula of *Planorbis*, a very common pond snail, is shown in Fig. 69. The number varies greatly in different Gastropods, the carnivorous forms having as a rule fewer but more powerful teeth than the plant-eating forms.

When the snail is feeding, the lips are retracted and the cushion and rasp pushed forwards until the latter can be scraped against the surface on which the snail is feeding. If the snail is feeding on the Algae which have covered the sides of the tank, the passage of the tongue over the glass is indicated by the clean tracks left where the Algae have been scraped away.

Naturally the teeth on the rasp rapidly become worn down by this scraping action, but just as rapidly are they replaced by the pushing forward of fresh teeth from behind. The

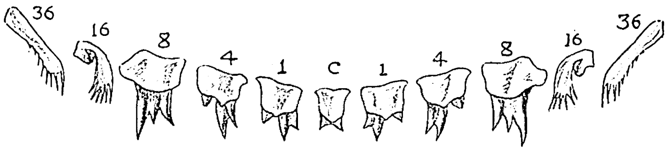

FIG. 69.—Radula of *Planorbis*.

A few of the 73 teeth from one transverse row; *c*, central tooth of the row.

formation and growth of the new teeth occur at the hinder end of the rasp, which is lying in the regenerative "tongue sac"; the whole structure, as it is renewed from behind, gradually grows forward, and so a constant supply of teeth is forthcoming.

Senses. The sense of *sight*, in spite of the presence of eyes, does not seem at all keen, the keenest senses being those of touch and of smell (the tactile and olfactory senses). The whole body seems sensitive to touch, particularly the tentacles, which are also the seat of the special sensory cells thought to be olfactory in function.[1] The sense of taste is probably located in the upper lip, which, in some forms, is curiously lobed. There is no proof that a purely auditory sense is present, apart from the tactile sense, which would be affected by any strong vibration due to a sound. The sensitiveness of water snails to various stimuli has not, however, been very fully worked out.

[1] J. W. Taylor, *Monograph of the Land and Fresh Water Mollusca of the British Isles*, vol. i. pp. 224-30.

Reproduction. Although *Limnaea*, like all air-breathing snails, is hermaphrodite, cross fertilisation takes place, the sperm cells being passed from one snail to another through a special tubular structure known as the "penis." The male aperture is just below and behind the right tentacle; the female duct opens further back, just in front of the pulmonary aperture.

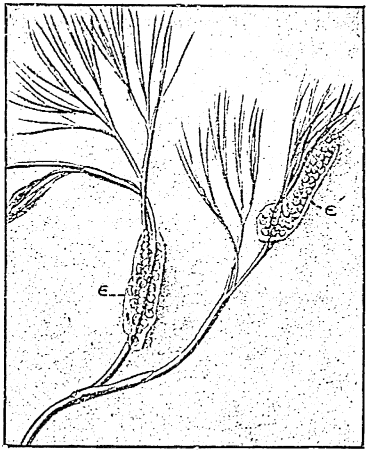

FIG. 70.—*Limnaea stagnalis*.
Two masses of eggs (*e* and *e'*) attached to a branch of water-crowfoot.

The eggs are laid at intervals during the summer; they are deposited about thirty at a time, embedded in a curved mass of jelly, which is nearly an inch long; this is usually deposited on some water-weed to which it adheres. The young snails hatch in about a month. They do not at once need to rise to the surface for a supply of air, for they are hatched with the lung-cavity full of water, and probably they are capable of respiration through the skin, using the air dissolved in the water.

Growth. The growth of the young snail is fairly rapid at first; in three months the shell may be nearly an inch long, but the full size is not attained for two years. The rate of growth depends on the temperature and the volume of the water in which the snail is living, as well as on a plentiful supply of food; the optimum temperature for growth is said to be about 25° C.; below 12° C. the snail may exist quite healthily, but will not grow. The variation in size according to the volume of water in which the snail is reared is very marked—even after a week a difference can be detected between the size of snails kept in a small vessel and others from the same batch of eggs kept in a much larger tank; the less the amount of water the smaller the shell, other conditions being similar and favourable. *Limnaea* may live five years.

Hibernation. *Limnaea* seems to spend the greater part of the winter in a state of torpor, buried in the mud at the bottom of the pond and breathing probably through its skin; it does not hibernate completely, however, and has been seen even on a day when the pond was frozen over, crawling about on the under side of the transparent ice.

Enemies. The water snail is preyed upon by a good many other creatures; ducks and water-shrews devour it, the Carnivorous Water Beetle (*Dyticus marginalis*)—the "shark" of the pond—feeds on it, frogs and toads will snap it up when small, and sticklebacks and other fish eat a great quantity of the eggs before they hatch and of the recently hatched fry.

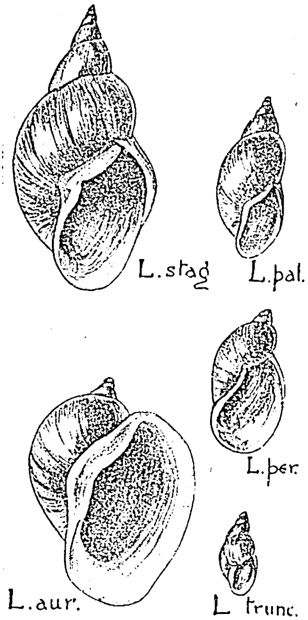

FIG. 71.—The Shells of some common species of *Limnaea*.

L. stag., Limnaea stagnalis; *L. pal.*, L. palustris; *L. per.*, L. peregra; *L. aur.*, L. auricularia; *L. trunc.*, L. truncatula.

Other Common Air-breathing Water Snails.

There are four chief genera of lung-breathing water snails, and there are several species of each genus that are very common in our ponds; these will be now briefly enumerated and shortly characterised, so that they may be recognised when found.

Genus Limnaea. Belonging to the genus *Limnaea* are all water snails with thin, horn-coloured, spirally-coiled, conical shells, and having two triangular, non-retractile tentacles, with an eye at the base of each.

Limnaea stagnalis (*the Common Pond Snail*) (Figs. 67 and 71).—This is the species fully described above. Size $1\frac{1}{2}$ to 2 inches. Whorls 6 to 8, the last one relatively very large. Mouth of shell rather more than half the whole length of the shell.

Limnaea palustris (*the Bog Snail*) (see Fig. 71).—This is a smaller species, with shell $\frac{1}{3}$ to 1 inch long. Whorls 6 or 7, and narrower than in *stagnalis*; shell browner and thicker, mouth narrower. Rather too fond of delicate plant food to be a desirable inhabitant of a tank; also apt to escape from the tank unless covered; 60 to 80 eggs are laid in a roughly cylindrical capsule.

Limnaea peregra (*the Wandering Snail*).—Shell $\frac{3}{4}$ inch long; 5 whorls. Body whorl, and also the mouth of shell, very large; outer lip a little reflected; very common. Feeds on decomposing animal matter as well as on vegetation; apt to leave the water, migrating to damp meadows or even finding its way up willow trees; 60 to 80 eggs are laid in an elliptical capsule.

L. auricularia (*the Ear-shaped Snail*).—Is similar to *peregra*, but the body whorl and mouth of shell even larger relatively and more contracted by the penultimate whorl (Fig. 71). Shell $\frac{3}{4}$ inch to $1\frac{1}{8}$ inch long; 4 or 5 whorls. Not so common as *peregra*, but found in most parts of Britain; eggs laid in a double series embedded in a long band of jelly.

L. truncatula (*the Dwarfed Limnaea*).—Shell $\frac{2}{5}$ to $\frac{1}{2}$ inch long. Whorls 4 to 5; suture deep, umbilicus distinct as a small chink behind the reflected lip of the shell. Found in rather muddy water, but also out of the water. (For connection with the life-history of the Liver-fluke see p. 102.) Eggs laid 12 to 20 together, in jelly capsule in the mud; hatched in 16 to 20 days.[1]

Genus Planorbis.

The "Flat-coil" Snails.—These are aquatic snails having flat, spirally coiled shells, each whorl lying on the outer side of the one before, but in close contact with it. The colour of the body and shell is usually dark, and the single pair of tentacles non-retractile, long and thin. The foot is smaller and shorter than in *Limnaea*, with a blunter end. The breathing aperture is on the left side, and the lobe of the mantle, close to the aperture, is itself vascular and may function as a respiratory gill below water[2] (Fig. 72, *C*).

Planorbis corneus (*Common Trumpet Snail or Ram's-horn*).—

[1] There are several other species of *Limnaea*, but they are not very common.

[2] J. W. Taylor, *op. cit.*, vol. i. p. 304.

Shell $\frac{3}{4}$ to 1 inch in diameter, rounded on both sides. Whorls 5 or 6. Dark reddish-brown in colour, very common in some localities, and always to be had readily from any dealer in aquatic specimens. Eggs 20 to 45 in a flat, oval capsule attached to a leaf. Rasp with 67 teeth in each row, and 200 rows.

Planorbis complanatus (= *umbilicatus*).—Shell $\frac{3}{4}$ inch diameter; 5 or 6 whorls. One side of the shell is flat or

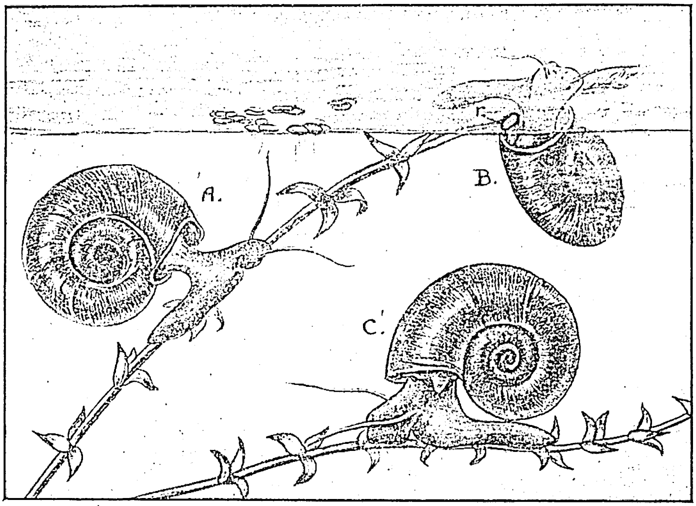

FIG. 72.—The Common Trumpet Snail (*Planorbis corneus*).

A, Climbing a piece of Canadian water-weed. *B*, Breathing at the surface; *r*, respiratory aperture. *C*, Seen from the left side, showing the projecting respiratory lobe of the mantle.

concave, and hence there is a distant *keel*, quite on one side of the middle line of the outer whorl. Mouth of shell rhomboidal.

Planorbis vortex (*the Whirlpool Trumpet Snail*).—Shell $\frac{3}{8}$ inch in diameter. Whorls 6 to 8. One side of the shell is convex, and one flat, and consequently here also there is a *keel* on one side of the body whorl. This species, which is fairly common, can endure drought, lying in a torpid state with the mouth of the shell closed by an "epiphragm."[1]

[1] For explanation of this term see p. 133.

Planorbis contortus (*the Twisted Trumpet Snail*).—Shell $\frac{1}{5}$ inch in diameter. Whorls 8, very similar to *vortex*, but about half the size and more common; rather a sluggish snail. The shell has a crescent-shaped opening, is much compressed, and has no keel; the left side is deeply concave. Widely distributed, but rather local.

Planorbis spirorbis (*the "Round-spired" Trumpet Snail*).—Shell $\frac{1}{4}$ inch in diameter. Whorls 5 or 6. One side of shell concave and one flat or concave; keel rather blunt. Common in stagnant shallow water or grass.

Planorbis carinatus (*the Keeled Trumpet Snail*).—Shell $\frac{1}{2}$ inch in diameter, with 5 or 6 whorls only; a distinct keel running down the *centre* of the whorl.

There are many other species which are not, however, so common, and the characteristics of which have not in many cases been very clearly determined.

Genus Physa. *The Bladder Snails* are easily recognised by the much-polished *sinistral* shell (see p. 112). They are active little creatures, with long, slender tentacles, and with the habit of supporting themselves in the water by mucous threads, on account of which they are sometimes called "Thread-spinners."

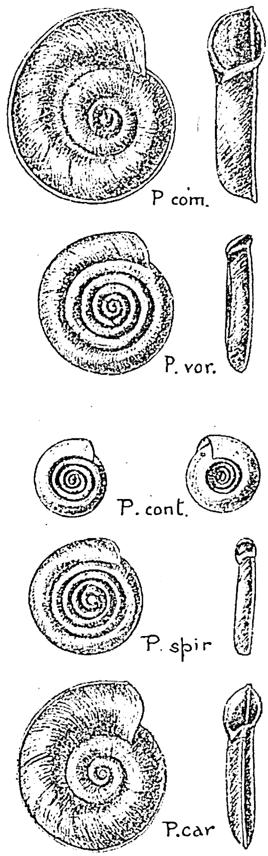

FIG. 73.—Some common *Planorbis* species.

P. com., P. complanatus (slightly enlarged); *P. vor.*, P. vortex × 2; *P. cont.*, P. contortus × 2; *P spir.*, P. spirorbis × 2; *P. car.*, P. carinatus × 2.

Physa (= *Aplecta*) *hypnorum* (*the Moss Bladder Snail*).—Shell $\frac{1}{2}$ to $\frac{3}{4}$ inch long, 5 or 6 whorls. Glossy yellow or reddish, aperture of shell pear-shaped (see Fig. 74, *P.h.*). No finger-like processes extend from the mantle over the shell. Of rather local occurrence.

Physa fontinalis (*the Fountain Bladder Snail*).—A very common form on water-cress beds; rather smaller than the Moss Bladder Snail. Shell $\frac{1}{4}$ to $\frac{1}{2}$ an inch long; 4 or 5 whorls. Body whorl relatively very large, and spire very short (see Fig. 74, *P.f.*). The body is characterised especially by the finger-like processes of the mantle which are reflexed over the shell.

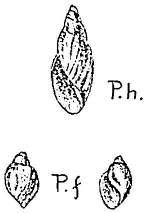

FIG. 74.—*P.h.*, Shell of *Physa hypnorum*; *P.f.*, shell of *Physa fontinalis*.

Genus Ancylus. *Hooked Snails.*—These forms are sometimes known as Freshwater Limpets, for they cling closely to the weed or stone on which they are living, and are therefore liable to be overlooked. The shell is thin, brittle, and hood-shaped, with an incomplete spire. They move slowly, and rarely come to the surface to breathe. When moving, very little of the body shows beyond the shell.

Ancylus fluviatilis (*the River Limpet*).—Shell $\frac{1}{4}$ to $\frac{1}{3}$ inch; spire curved to the right, or centrally placed over the body whorl; respiratory opening on the left. Found only in streams, often on the aquatic "willow moss."

FIG. 75.—Shell of *Ancylus fluviatilis*.

Ancylus lacustris (*the Lake Limpet*).—Shell $\frac{1}{10}$ to $\frac{1}{4}$ inch. Spire twisted to the left, respiratory opening on the right.

Pond Snails which have Gills.

These snails breathe below the surface of the water by means of a plume-like gill which lies within the mantle

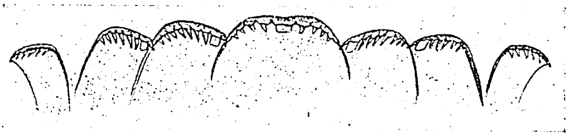

FIG. 76.—One Row of Teeth from the Radula of *Paludina*.

cavity attached to the mantle. They all possess an *operculum*, a horny and calcified plate carried above the foot, which,

when the animal withdraws into its shell, just fits into and closes the mouth of the shell. This operculum is formed as a cuticular structure by the secretion of a group of cells on the dorsal side of the foot, at its posterior end.

Genus Paludina. *Freshwater Winkles.*—These snails are viviparous, *i.e.* the eggs are hatched within the body of the mother; the fry are not set free until they are at least two months old, when they are gradually ejected, two or three at a time. The two British species of this genus are both large snails having a shell of 6 or 7 whorls with very convex surfaces; in both of them the foot bears on its upper surface a horny plate, or "operculum," with irregularly concentric lines of growth on it. When the snail withdraws into its shell, this plate completely closes the aperture. There are two tentacles, with an eye placed on a little tubercle on the *outer* side of the base of each. The mouth is borne on a prominent snout.

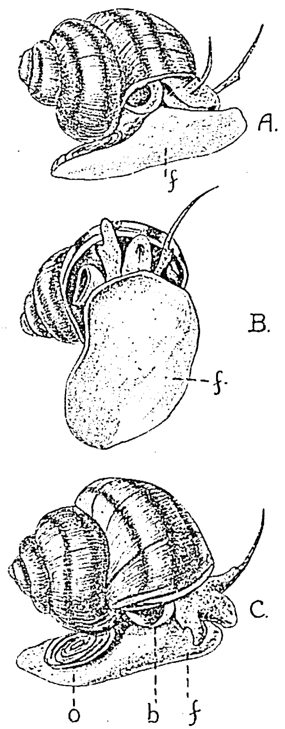

FIG. 77.—*Paludina vivipara.*

A, Female snail; *B* and *C*, males; *f*, foot; *b*, breathing aperture; *o*, operculum.

Paludina vivipara (see Fig. 77).—This species is fairly common in ponds and slow-flowing streams. The body is dark, speckled with yellow. The shell has a rather thick operculum, and there are three dark bands on the body whorl of the shell, running spirally round it. The form of the teeth on the rasp is shown in Fig. 76.

Paludina contecta.—This species is not so common as *vivipara*, though not rare in the south of England. It is slightly larger than the other species and the shell has a thinner operculum, more swollen whorls, a more pointed spire, and a more distinct umbilicus. It is a very irritable creature, falling with surprising rapidity from

the glass of the tank if this is tapped whilst the snail is climbing up it. In the male the right tentacle is shorter and thicker than the left.

Genus Bithynia. *Bithynia*[1] consists of much smaller forms which are oviparous; the eyes are sessile; the operculum is calcareous and therefore hard and brittle; the tentacles are thread-like and are both the same size in the male. The eggs are laid in two rows in a gelatinous ribbon, each egg

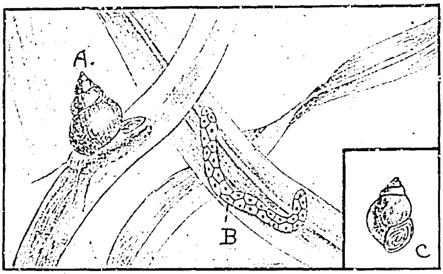

FIG. 78.—*Bithynia tentaculata.*

A, Snail extended, showing operculum; *B*, eggs; *C*, closed shell seen from below.

being surrounded by a definite hexagonal area of jelly (see Fig. 78).

Bithynia tentaculata.—Shell $\frac{1}{2}$ inch long and with 6 whorls; aperture of shell oval. This is rare in the north of England.

Bithynia Leachii.—Shell $\frac{1}{4}$ inch long and with only 4 whorls, also the whorls are more rounded; aperture of shell nearly round. This form is only found in the south of England.

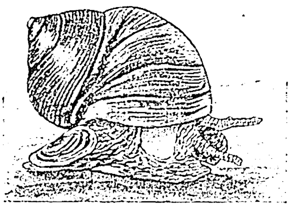

FIG. 79.—The Common Periwinkle.

Marine Univalve Molluscs.

Genus Littorina. Periwinkles. One species of this genus is *Littorina littorea*, the Common Periwinkle, very similar in structure and habits to *Paludina*,

[1] The name means "inhabiting deep water," but it is rather misleading as this snail lives in ponds with *Limnaea* and *Planorbis.*

but living in the sea between tide-marks and feeding on seaweeds. These "winkles" are largely used for food; nineteen hundred tons are said to be annually consumed in London alone!

Cypraea. The Cowry. The Cowry is another carnivorous gill-breathing marine snail, the shell of which is very thick and hard; the orange-coloured mantle is reflected for some distance up each side of the white shell (Fig. 80).

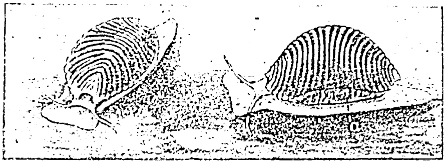

FIG. 80.—The Common Cowry (*Cypraea* (*Trivia*) *europoca*).
a, The reflected mantle.

Genus Buccinum. Whelks. *Buccinum undatum* is the Common Whelk or "buckie," a large snail, having an operculum, and breathing below the water by a gill, but differing

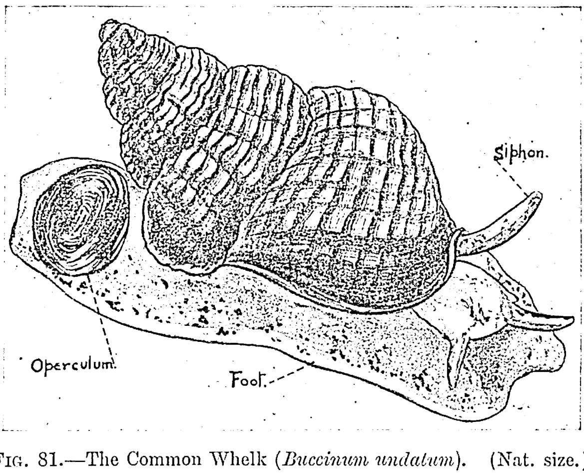

FIG. 81.—The Common Whelk (*Buccinum undatum*). (Nat. size.)

from periwinkles, or freshwater winkles, in being carnivorous; also the mantle round the respiratory aperture is drawn out

into a long, trough-shaped siphon, causing a distinct notch in the margin of the shell on the left side. The whelk feeds on decaying animal matter, but also on living "shell-fish," such as oysters or periwinkles, sucking out their soft bodies through a hole bored right through their shells by its strong-toothed rasp, which is carried inside a protrusible snout. This rasp may be an inch long, and bears 220 to 250 sharply-pointed teeth (Fig. 82).

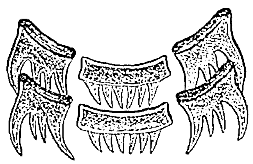

FIG. 82.—Two Rows of Teeth from the "Rasp" of a Whelk.

The *eggs* of the whelk are well-known seaside objects, for they are very often thrown up on the beach by the waves. They are laid in little horny capsules, which are fused together in a sponge-like mass, often in clusters of a hundred or more. Each capsule contains 500 to 600 eggs, but a few of these develop more rapidly than the others, devouring their brethren, so that only 5 or 6 finally hatch from each capsule. The eggs are laid in the autumn, but the little larvae do not leave the egg-case until the spring. They are able at first to swim freely in the water.

FIG. 83.—*Buccinum undatum.* A small Cluster of Egg-capsules.

Nassa, The Dog Whelk. *Nassa reticulata*, the Dog Whelk, may be found near low tide mark crawling over the rocks or sand at the bottom of the water, or completely buried in the sand except for its waving respiratory siphon. The broad yellow foot is speckled with black, and has a horn-like process on each side of its broad front end and two small pointed "tails" at the back end. The egg-capsules are little flat pouches often fastened in rows on some seaweed.

Purpura, The Dog Winkle. *Purpura lapillus*, the Dog Winkle, is allied to the whelks. It abounds on the British coasts. It will itself live well in an aquarium, though it may kill and eat other molluscs, boring their shells with its proboscis. Its egg-capsules are like clusters of little yellow or pink grains of rice, each set on a tiny stalk. From this creature can be obtained a beautiful purple dye by crushing it so as to

break open a little sac behind the head and set free the tiny drop of secretion in it; this is at first cream-coloured, but on exposure to light becomes purple.

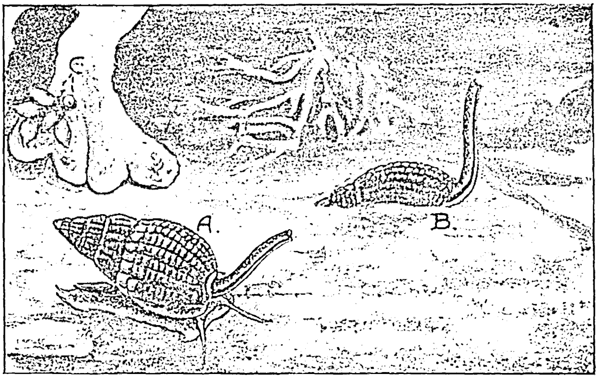

FIG. 84.—The Dog Whelk (*Nassa reticulata*).

A, Crawling over the bottom of a rock pool; *B*, at rest, partly buried in the sand; *E*, eggs attached to a stalk of seaweed.

The Murex.

The genus *Murex* is interesting because of the Spiny Murex, the Mediterranean species, from the secretion of which the very highly valued "Tyrian" purple used to be mainly obtained in ancient times. *Murex erinaceous* is the British Sting Winkle.

Patella. The Limpet.

Patella differs from those thus far considered, in having a simple conical shell, and also in having —instead of the typical gill of the others—a ring of delicate vascular, plate-like outgrowths from the under surface of the mantle, which can be projected just beyond the foot. It is in these plates that the blood is aerated. The Common Limpet (*Patella vulgaris*) lives in great numbers all round our coasts, clinging so closely to the rocks when these are left uncovered at low tide, that water is shut into the shell, and so the gills are kept moist till high tide again. When sub-

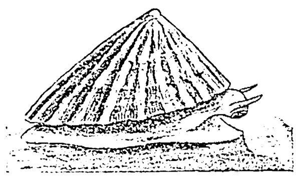

FIG. 85.—The Common Limpet (*Patella vulgaris*).

merged, the animals loosen their hold and move about, feeding on seaweed, but each returns to the same rock after feeding and often wears away a little basin by constantly clinging to the same spot—its own little foothold of land.

Practical Work on Univalve Molluscs

How to start a Freshwater Tank. In order to keep water snails under close observation, a *freshwater tank* is necessary. A rectangular tank is best, either one made entirely of glass, or one of wood and glass, such as that the construction of which is fully described in *Fresh Water Aquaria*, by G. C. Bateman. The aquarium should stand, if possible, in a north window, and should be covered with a sheet of glass. If in a sunny window, the side of the tank next the window must be shaded with a curtain. The floor of the tank should be covered with a layer, one or two inches deep, of small stones, which have been well washed by stirring them in running water, until the water that passes off is quite clear and bright. In this gravel some healthy plants must be established before any animals are put into the tank. When snails are to be kept, it is well to put in plenty of some very common weed, such as the Canadian waterweed, as the snails eat a great deal, and would soon destroy rarer and more delicate plants. This weed will grow floating freely in the water, but it is best to tie it down to a stone, in bunches of seven or eight pieces, and then bury the stone in the gravel at the bottom of the tank, so that the bunches of weed stand up in the water. When the weeds are thriving, so that bubbles of oxygen gas are seen rising from the leaves through the water, the snails, and, later, other creatures, may be introduced. In a well-balanced tank the water should never need changing.[1]

How to get the Snails. The snails may be obtained from any pond in which there is plenty of vegetation, by drawing a fishing-net through the weeds. They may be carried home in a tin; if plenty of water-weed is put in to keep them damp, no further water is necessary for a few hours.

Suggestions for practical Work. The snails should be watched, sketches made of them in several different positions, and their habits noted. After they have been in the tank a little while, their egg-masses may be found. The day should be noted on which one such mass is deposited, and a record kept of the history of the development of the eggs. If there are fish in the tank,

[1] Pond water or clean rain water is the best to use, but ordinary tap water usually answers quite well, unless exceptionally hard.

the weeds to which the egg-masses are attached should be removed and kept in a shallow dish of water apart, for fish will feed greedily on the young snails as they hatch. Different batches of eggs should be kept under different conditions as to warmth and the volume of water in which they are reared, and the effect of the variations on their rate of development noted.[1] The volume of water should be varied from 100 to 200 c.cs. a creature, and the temperature from about 12° C. to 25° C., which will probably be found to be the minimum and optimum temperatures for growth. The young snails should be given plenty of free-floating filamentous Algae for food.

Slides showing the structure of the radula in several different snails should be made or obtained, and examined under the microscope.

Periwinkles, *Cowries*, *Limpets*, *Dog Whelks* and *Dog Winkles* may be kept in the sea-water tank described at the end of Chapter III., but only one or two at a time, and care must be taken that the water is kept well aerated. Periwinkles are very apt to escape, so the tank must be kept covered; their predilection for leaving the water should, however, be considered, and the rock-work in the tank built up above the water surface. Dog whelks and Dog winkles should be kept in a tank with a sandy bottom, for they like to bury themselves in the sand, leaving only the waving siphon to mark their hiding-place.

[1] Compare Semper's results given in *Animal Life*, Int. Sci. Series, vol. xxvi. pp. 161-64.

CHAPTER X

PHYLUM X.: MOLLUSCA (*continued*)

Air-breathing Land Snails

Land snails are characterised by possessing two pairs of hollow tentacles, the eyes being placed at the tip of the hinder longer pair.

The shell may be well developed and spirally coiled, or it may be absent, or represented by a few calcareous particles only, as in many slugs.

No land snail has a true operculum, and all are hermaphrodite.

Type: The Common Garden Snail (*Helix aspersa*).

One striking point of difference between the shell of a land snail and that of a pond snail is the greater thickness and strength of the former. The thickness of the shell seems to vary with the nature of the soil, and the consequent character of the plants on which the snail feeds.

The Shell. In *Helix aspersa* the shell is fairly thick and is spirally coiled, but the spire lies quite to the right of the body whorl, and is much blunter than in *Limnaea stagnalis*. The *umbilicus* (see page 113) is hidden by the reflexed lip of the shell.

The colour of the shell is yellowish, with spiral dark reddish-brown bands running round it. There may be as many as five of these bands on the body whorl, but frequently some are confluent. The bands are always interrupted, more or less, by transverse irregular streaks of white or yellow. The white lip of the shell is thickened, and turned outwards.

The structure of the shell and the mode of growth are essentially similar to that of *Limnaea* and of all other snails. The natural length of life of land snails seems somewhat greater than that of pond snails; *Helix aspersa* lives five or six years, though, as a rule, not more than two or three annual lines of growth are to be seen on the shell, possibly for the reason that growth ceases in the second or third year of life.

Land snails have no true operculum; before they hibernate, they retire to some sheltered corner, often burrowing into the loose soil; then the mouth of the shell is closed by

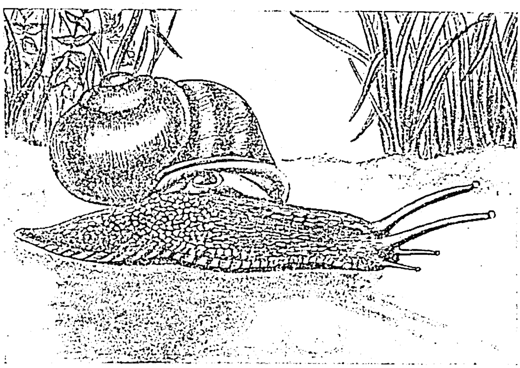

FIG. 86.—The Common Garden Snail (*Helix aspersa*).

a thin membranous plate or *epiphragm*, formed from a discharge of mucus and calcareous matter from the collar or thickened rim of the mantle. This mucus at first fills the mouth of the shell, and is often separated from the body by a discharge of air from the lung, becoming convex at first, but sinking in again, and gradually becoming flat or concave. It hardens into an opaque plate, which, however, remains permeable to air.

A somewhat similar epiphragm is often formed in the summer during a temporary drought, but in this case it is much thinner, less calcified, and often perforated in the centre of a specially calcified opaque spot opposite the breathing aperture.

Structure of Body.

The colour of the body is a dark brown or grey, speckled with the milky-white spots which give to it its specific name, "aspersa," signifying "sprinkled." The foot has a yellow band round it.

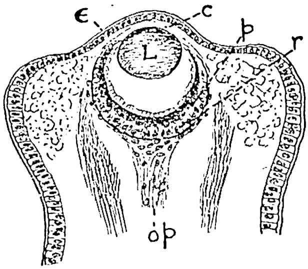

FIG. 87. — Longitudinal section through the tip of one of the long tentacles of *Helix* to show the structure of the eye.

e, Epidermis; *L*, lens; *p*, pigmented layer; *r*, retina; *op*, optic nerve.

The form of the body of this snail is very similar to that of *Limnaea*, although in *Helix* there are four tentacles on the head instead of two, and at the tip of each of the longer, upper pair is a fairly complex eye, which can be readily seen as a little black dot.

This *eye* contains a solid lens, behind this a pigmented layer, and then a layer of sensory cells in connection with the optic nerve (see Fig. 87). In spite, however, of the considerable complexity of the organ, the sense of sight does not seem at all keen.

The *tentacles* are hollow, and can be retracted by means of a special muscle which is visible through the semi-transparent wall of the tentacle, running inside it from base to apex (see Fig. 88).

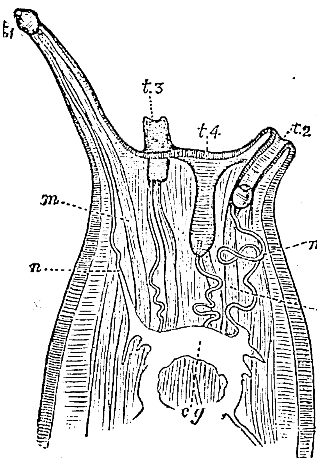

FIG. 88.—Longitudinal Section of the Head of a Snail. (Diagrammatic.) (After Furneaux.)

t^1, Long tentacle extended; t^2, long tentacle withdrawn; t^3, t^4, short tentacles; *m*, muscles; *n*, nerves.

When this muscle contracts, the tip of the tentacle, with the eye, is drawn down inside the tentacle, and so the eye is protected. The position of the eye and optic nerves, and the muscles which cause by their contraction the turning "outside in"

of the tentacle, can be seen in Fig. 88, which represents a section of the head taken through the long tentacles, and which also shows the short tentacles in front.

The *mouth* is provided with a single hard upper jaw against which the rasp works. It shows as a black curved bar when the mouth opens (Fig. 89). The *rasp* has 107 teeth in each row, and 145 rows, so that—with such a formidable weapon to use—the damage done by this snail is not surprising.

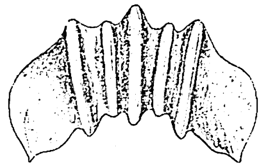

FIG. 89.—*Helix* jaw, much enlarged.

The "*lung*" *cavity* lies in the body whorl, and opens to the exterior on the right side. The aperture is easily seen, and stays open for a considerable time. The method of breathing is similar to that described on p. 115 in the account of the pond snail, *Limnaea*. It is illustrated by Fig. 90, in which part of

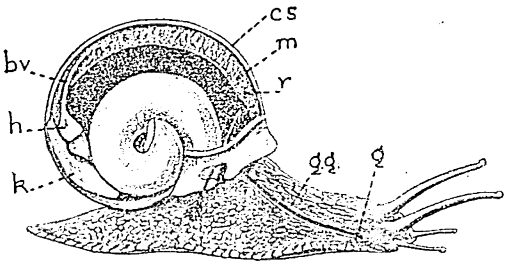

FIG. 90.—*Helix* dissected from the right side.

r, Respiratory cavity; *m*, vascular mantle; *cs*, cut shell; *h*, heart; *bv*, blood-vessel carrying blood to the heart; *k*, kidney; *gg*, genital groove; *g*, reproductive aperture.

the right side of the body is supposed to be cut away, thus exposing the respiratory cavity and the structures in relation with it.

The *blood* of Helix is colourless when impure, but blue when oxidised, for the oxygen carrier, which is dissolved in the blood, is not haemoglobin but haemocyanin, a copper compound. This is characteristic of most snails, though in a few, *e.g. Planorbis*, haemoglobin is found and the blood is red.

Movement. The Trail. A snail is a slow walker; it is said to take about fifteen days to travel a mile. Living on the ground, it has often to make its way over rough surfaces; to obviate the hindrance this might be to its slow gliding motion, the snail discharges a mucous substance from a special "pedal" gland, which opens at the upper front end of the foot, just below the mouth. The mucus forms a smooth bed over which the sole of the foot can easily glide. It is this that causes the slimy trail left behind by a snail.

These trails enable us to learn something of the snail's wanderings at night in search of food. It will go relatively long distances and climb walls to reach some favourite food, and yet—as the trail tells us—it will return to its original home after it has fed. This "homing instinct" seems curiously well marked in snails.

The Sense of Smell. The sense of smell is well developed, and the concentration of special sensory cells in the longer tentacles seems to suggest that these organs have a special olfactory function as well as that of bearing the eyes; probably the shorter tentacles also possess this sense, and possibly even to some extent the whole soft skin. The olfactory sense seems much more developed in snails than the sense of sight.

The Sense of Taste. In all univalves the sense of taste is probably located in the upper lip, which is always very mobile and sensitive, and often curiously lobed. This lobing is well seen in the Black Slug (*Arion ater*), and in many others, but is not so marked in *H. aspersa.*

The Sense of Hearing. Some experiments made by Mr. Bateson suggest that sounds of a special pitch cause a reaction in certain bivalve molluscs, and it may be that snails too have some sense of hearing, but this has not been proved; the little sacs containing calcareous particles supported by cilia that occur embedded in the flesh of the foot are more probably organs for regulating balance.

Hibernation. Hibernation usually begins in October, when snails are in specially good condition. The snail may merely hide itself in some crevice in a wall, usually behind ivy, or it may bury itself in loose earth, always with the mouth of the shell uppermost, and over this it forms the epiphragm. If the winter is a very cold one, the

body contracts farther and farther into the shell, and fresh epiphragms are formed one within the other. As many as six have been found in *Helix aspersa*.[1] It is stated that in some districts with calcareous rocks *H. aspersa* excavates tunnels in the rock, each tunnel being about one inch in diameter and three or more inches long. It is thought that the wearing away of the rock is chiefly due to the friction of the foot, but the rubbing action is doubtless aided by an acid secretion, for in such situations the recently exuded slime from the foot shows an acid reaction with litmus.

Reproduction. Land snails are all hermaphrodite. They have a single reproductive gland, lying on the visceral hump, which contains both ova and sperms, and which is therefore called the *ovo-testis*. The sperms, however, develop first, so that each individual snail is first male and later female in function. In *Helix* the common ova-sperm duct opens on the right side of the head (Fig. 90, *g*). At the time of mating, a small tube, the penis, protrudes from the temporarily "male" individual and enters the genital aperture of its mate, introducing a tiny, long packet of thread-like sperm cells which are stored away in a special sac inside the second snail until needed. *H. aspersa* lays from 40 to 100 eggs at a time, in a hole in moist earth. They are round transparent objects about $\frac{1}{8}$ inch in diameter. Several batches of eggs may be laid during one summer.

Some snails, *e.g. Helix aspersa* and a number of other species of this genus, have, when full grown, in connection with the reproductive organs a curious "dart-sac." This is a muscular sac containing a little angular structure known as the "love-dart," for it is discharged by one snail into the body of the snail with which it is about to mate. The actual function and origin of this remarkable dart is not very certain.[2]

Other Common Species of the Genus Helix.

Helix hortensis (the White-lipped Snail).—A rather smaller species than *H. aspersa*, with distinct darker spiral bands

[1] J. W. Taylor, *op. cit.* on page 118.
[2] See *Camb. Nat. History*, vol. iii., Mollusca.

of colour on the shell, not crossed by transverse white bands. The shell is 1 inch across, and it has $5\frac{1}{2}$ whorls; the lip is white.

Helix nemoralis (the Grove Snail or Brown-lipped Snail).—The shell is 1 inch across, very varied in colour, often clear yellow, with one to five spiral dark bands running round it; the lip of the shell is reflected and usually brown; there is no umbilicus; the body is brown, tinged with yellow; very like *H. hortensis* except for the brown lip. This snail is very common in hedges, and is often found feeding on stinging nettles.

Helix pomatia (Apple or Roman Snail).—This is a large snail common in calcareous districts. The shell is $1\frac{3}{4}$ inch across, and is thick, strong, yellowish, or pinkish-white, with spiral light-brown bands; the outer lip of the shell is thickened; the umbilicus is small but distinct (Fig. 91). A peculiarly solid calcareous epiphragm is secreted by the mantle before the winter, and may be found discarded on the ground in spring. Before hibernating, each snail excavates with its foot a hole, which it roofs in and lines with earth and dead leaves, making with its slimy mucus a kind of mortar, which it smooths over the walls. The winter sleep continues usually until April.

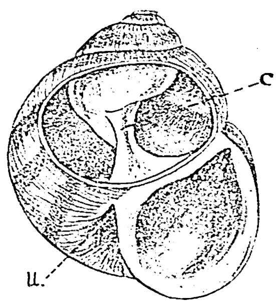

FIG. 91.—Shell of *Helix pomatia* cut so as to expose the Columella "c" and Umbilicus "u."

The *eggs* are the size of small peas, and have much the colour and consistency of mistletoe berries. They are laid in June, in a hollow in the earth. The young hatch in from 21 to 45 days and make their first meal off their egg-shells.

M. Gaspard has experimented to test the sight of these snails, and believes that they are quite blind, and that the so-called "eyes" are only touch organs.[1]

[1] M. Gaspard in *Annales de Sciences Nat.*; Professor Bell in vol. i. of *Zoological Journal.*

Other Common Genera of Land Snails.

Bulimus.—The shell in this genus is oblong, with the whorls drawn out into a long spire and the lip usually reflected. Frequent on open downs near the sea-coast; very similar to *Helix*, except in relative length of spire. Its generic name seems to bear reference to its insatiable appetite, for it means "the greedy one"!

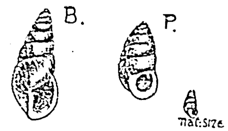

FIG. 92. — *B. Bulimus montanus* (nat. size); *P*, *Pupa cylindracea* (enlarged, but with natural size shown below).

Pupa (the Chrysalis Snail).—Small gregarious forms found in moss or crevices in walls or amongst roots of grasses; shell cylindrical, and spirally coiled, the last whorl only slightly, if any, bigger than the preceding one; the tip of the spire forms a sharp point. The mouth of the shell is bordered with one or more teeth.

Vertigo.—A very small form, like *Pupa*, but with only two tentacles, the lower front pair being absent; shell in some species sinistral (see p. 112 for term) and only $\frac{1}{16}$ to $\frac{1}{12}$ inch long.

Clausilia (the Door-shell Snail).—Some species common on bark of trees, and under stones. Shell sinistral, with a long pointed spire. The mouth of the shell is closed by a *clausilium*, a small white convex plate attached by a somewhat cartilaginous, spirally-twisted, elastic foot-stalk, to the columella in the penultimate whorl. When the animal emerges from its shell, the clausilium is pressed to one side out of the way, but on the snail retiring again, it springs back into position over the mouth of the shell. This curious little structure is not present in the young snail, being only formed as it approaches its maturity. *Clausilia* has four tentacles, but the two lower ones are very short.

The Enemies of Snails.

The chief enemies of snails are the various birds which feed on them, particularly the thrush, which often has a special table-stone on which it smashes successive victims, holding them by the lip of the shell, and breaking the spire on the stone.

Gardeners also are the snails' constant enemies, on account of the very great damage the latter do in a garden; for whilst most wild plants have acquired some more or less adequate defence against the ravages of snails—either by the forma-

tion of a surface covering of hairs, or by a secretion of silica or calcium carbonate which hardens the external tissues, or by the secretion of some such substance as tannin—cultivated plants have, as a rule, no such protection, and so fall easy victims to hungry snails. It is interesting to test the value of the various protective contrivances by giving snails a variety of apparently protected and unprotected plants to eat, and noting the results.

Uses of Snails.

Snails have been cultivated as an article of food even at so early a date as 50 B.C., and were considered a great delicacy by the Romans. Probably they were eaten also by the cave men of the Stone Age, for masses of *Helix* shells are found in their caves. Snail gardens are still to be seen in many parts of France and Spain. *Helix pomatia*, the Apple Snail, which is common in vineyards, is specially valued as an article of food, but several other species are also eaten.

Various concoctions of snails used to be made as remedies for many kinds of disease, especially for consumption, and the idea of their healing power in this disease still lingers in some parts of the country.

The shell of the Almond Whelk (*Fusus antiquus*), a marine species, used, in olden days, to serve the fishermen of the Shetlands for a lamp. It was suspended by a string, filled with fish-oil, and provided with a cotton wick.

Endurance of Snails.

Snails can withstand considerable extremes of cold and heat, and even drought, owing to the epiphragm, with which they prevent the complete loss of moisture from the body when they enter a state of torpor.

This is strikingly illustrated by the well-known case of the specimen of the Desert Snail (*Helix desertorum*), which was sent from Egypt to the British Museum in 1846, and fixed to a tablet there. Four years afterwards, when examining this mounted snail, Mr. Baird saw signs of the recent formation of an epiphragm; he removed the snail and put it in warm water, when it revived and came out of its shell! The next day it ate a meal of cabbage, and before long was quite normally active again, and mending its somewhat broken shell.[1]

[1] *Ann. Mag. Nat. Hist.* (2), vi. 1850.

Slugs.

Amongst the univalve Mollusca, slugs are peculiar on account of the rudimentary condition of the shell, which is represented in most genera merely by a small calcareous plate, or even by a few spicules only, hidden below the shield-like mantle. This mantle lies on the top of the long body; its margin is fused with the body all round, except where the respiratory aperture is left on the right side, leading into the lung-cavity lying below the mantle (Fig. 93). The theory that the shell has, in the ancestors of

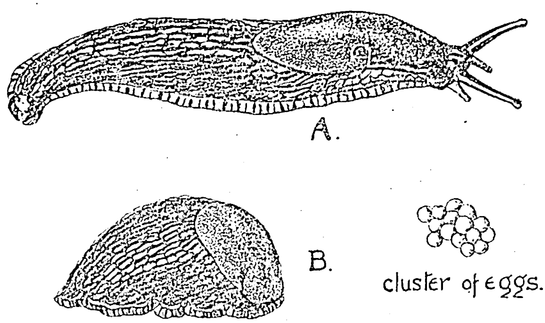

FIG. 93.—*Arion ater.*

A, Slug extended, showing the open respiratory aperture in the mantle; *B*, contracted.

these forms, been more fully developed, is upheld, not only by the vestiges of a shell that still remain, but also by the fact that in an early stage of the development of each individual a distinct spiral shell is present.[1]

In all slugs the wrinkling of the surface of the flesh is very marked, and also there is always one very distinct groove running parallel to the margin of the body, marking off the sole of the foot.

In the Common Black Slug (*Arion ater*), and in some others also, this border is marked by vertical lines, alternately

[1] J. W. Taylor, *op. cit.* page 118, vol. i. p. 201.

black and dusky, forming what is known as the *foot fringe* (Fig. 93).

The tentacles are similar in form and function to those of common garden snails.

Reproduction. Reproduction in slugs is generally very rapid. One pair of the common black slug (*Arion ater*) was kept under observation, and after pairing, it was found that one of the slugs laid 396 eggs in five separate batches, with an interval of about a week or ten days between each batch, whilst the other laid 477 in four batches. These eggs hatch about sixty days after being deposited, the little slugs burying themselves in the ground for four or five days without feeding, and then emerging nearly double their original size. They are not full grown until the second year, and usually live two seasons only.

Habits. Slugs generally spend the day lurking under stones or logs, or buried in the earth, coming out at night to feed. They do great damage to plants.

Like snails, they can secrete a copious flow of mucus from the foot, and make a trail along which they glide. Many slugs also use this mucus, at times, to form a rope, by means of which they can lower themselves from a height and then climb back again. When about to descend in this way, the slug attaches the mucus to some surface and then drops, the mucous string remaining attached to the end of its tail. When re-ascending, it turns round and climbs up, collecting the mucus in a mass near the tail.[1] (Compare with the mucous thread formed by *Limnaea*, see pp. 116-17.) In the winter slugs hibernate each in a little hole in the earth, with a covering of slime round their much contracted bodies. Some interesting experiments have been performed by Mr. Ashford, showing the gradual slowing of the heart action in them as the temperature falls.

Some Common Genera of Slugs.

Genus Arion. The genus *Arion* includes the common black slug which lives in woods and gardens and feeds on animal or vegetable matter—nothing seems to come amiss. The respiratory aperture is in the front half of

[1] Wallis *Nature*, October 1890.

the mantle-shield; the shell is represented by a few calcareous grains under the back part of the shield; a slime gland is present in the tail.

Arion ater if full grown may be 4 inches long when extended, but the body may be contracted into a lump (Fig. 93). The tentacles are swollen at the tip, and black; the colour of the body, though usually black, may be brown, red, yellow, or green; the shield is lighter than the rest of the body; the foot usually has a yellow border.

Arion hortensis is only half an inch long; it is common in gardens. The shell granules are compact, forming an oval mass; the body is marked with grey lines or stripes.

Genus Limax.

Limax is the genus which includes the large grey slugs. The shell is like a curved plate; it is covered by the hind part of the mantle-shield, which has usually concentric lines on it. The respiratory opening is in the back half of the mantle-shield. The foot has no slime gland.

Limax marginatus (= *Sowerbyi*) is the Tree Slug; the colour of its body is yellow or reddish-brown with black speckles, its slime is colourless, and its shell resembles shagreen. It is said to feed exclusively on lichens.

Limax flavus (the Cellar Slug) is 4 inches long and yellow, with white and black specks; it has yellow slime and a concentrically marked shield.

Limax agrestis (the Grey Field Slug) is usually about $\frac{4}{5}$ of an inch long and has a concentrically marked shield, an ash-grey body, and milky slime. It is a very common and destructive species, specially characteristic of damp spots.

Limax maximus may be as much as 6 inches long; its body is grey with black spots, tentacles long and purple, and shield regularly striate; the shell is oblong and half an inch long. It is said never, or very rarely, to feed on any green part of a plant.

Testacella, or the "Snail Slug."

The genus *Testacella* is peculiar amongst British slugs in being carnivorous; it preys on worms and on smaller slugs and snails, which it holds by means of the rows of little sharp teeth on its rasp, and then swallows whole, there being no jaw across the roof of the mouth for the rasp to rub against as there is in most snails. It is also characterised by possessing a distinct ear-shaped shell, with a small terminal spire of half a whorl.

This shell and the mantle-shield below it are placed quite at the hind end of a very long body. The yellow-brown body is marked by two conspicuous lateral grooves for disseminating mucus; unlike other snails its body is narrowest

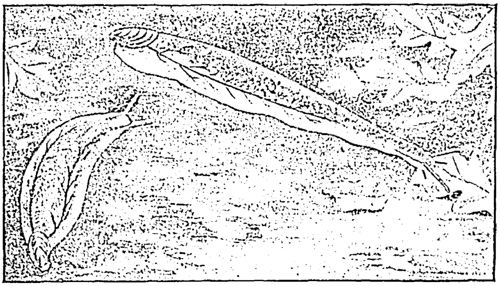

FIG. 94.—The Carnivorous Slug (*Testacella*).

in front and broadest at the hind end. This slug lives largely underground, and in cold weather forms a kind of cocoon of slime and earth. The eggs are laid singly, instead of in clusters as in most slugs. Each egg is about $\frac{1}{6}$th of an inch across.

Classification of the Univalve Molluscs or Gastropoda mentioned in Chapters IX. and X.

Order I. PULMONATA. Those breathing with a "lung"; hermaphrodite forms.

Sub-order 1. **Basommatophora.** Water snails in which the eyes are at the base of the non-retractile tentacles.

Family 1. Limnaeidae. Water snails with fragile dextral shells in which the lung-sac is protected by an external lobe of the mantle.

Limnaea, the Common Pond Snails.

Planorbis, the Trumpet or "Flat-coil" Snails.

Ancylus, the Hooked Snails or Freshwater Limpets.

Family 2. Physidae. Water snails with sinistral shells, over the margin of which the mantle is reflected.

Physa, the Bladder or "Thread-spinning" Snails.

Sub-order 2. **Stylommatophora.** Land forms with two pairs of hollow retractile tentacles, and with an eye at the tip of each of the upper pair.

Family 1. Helicidae (Garden Snails and the Black Slug). Land forms, with shell usually present, though represented only by calcareous grains in the slug; radula with a central tricuspid tooth.

Helix, the Garden Snail.
Arion, the Black Slug.
Bulimus, the "Greedy Snail."

Family 2. Pupidae. Forms in which all the whorls of the shell are of about equal breadth; the aperture of the shell usually has one or more teeth at its margin.

Pupa, the "Puppet Snail" or Chrysalis Snail.
Vertigo.
Clausilia, the Door-shell Snail.

Family 3. Testacellidae. Carnivorous slugs in which an exposed shell is usually conspicuous, though small, and is placed at the hind end of the long body. No jaw is present.

Testacella, the British Carnivorous Slug.

Family 4. Limacidae. Forms in which a rudimentary shell is present, but covered by the mantle.

Limax, the Grey Slugs.

Order II. Prosobranchiata. Water snails breathing usually by means of a single gill. They have one pair of tentacles, and the sexes are distinct.

Paludina, Freshwater Winkles.
Bithynia.
Littorina, Periwinkles.
Cypraea, Cowries.
Buccinum, the Common Whelk.
Nassa, the Dog Whelk.
Purpura, the Dog Winkle.
Murex, the Sting Winkle.
Patella, Limpets.
Fusus antiquus, Almond Whelk.

Practical Notes on Land Snails and Slugs

These Molluscs may be quite satisfactorily kept in a box of damp earth, partly covered by a piece of turf. Over the open box should

be placed a sheet of glass. Some cabbage or lettuce leaves should be put in for food, but these must be renewed every day.

After a time eggs may be looked for just below the surface of the earth. If possible, their development should be followed; care must be taken that they do not dry. *Testacella*, the Carnivorous Slug, will feed on the earthworms in the soil; its eggs are large and oval, and are laid singly. The behaviour of both snails and slugs at the approach of winter should be noted.

To see the contractions of the muscular foot, let a snail crawl up a sheet of glass, and examine from below.

To test the sense of smell and to compare it with that of sight, place attractive and odorous particles of food, such as a piece of rotten apple or of cabbage, first on one side and then on the other of a slug or snail, and then repeat the experiment, enclosing the food in a glass jar or tube through which no odour escapes. Note the reactions of the snail or slug.

To test the homing instinct of snails mark the shells of specimens found in a certain place in the garden with dabs of paint, and then visit the spot where they were found late that night and again the next morning. Do this for several days, and note the comings and goings of the snails. See if you can find their tracks, and follow them to their feeding-places.

CHAPTER XI

PHYLUM X.: MOLLUSCA (*continued*)

Class II.: PELECYPODA[1]
(Bivalve Molluscs)

Another group of Molluscs is characterised by the possession of a two-lobed mantle resulting in a bivalve shell. These two valves are equal in size in all freshwater bivalves, but in many marine forms, *e.g.* the oyster, one valve is much larger than the other. During life the body can be completely withdrawn into the shell, and the two valves held tightly closed by special muscles which are developed at both ends of the body, attaching it to the valves of the shell. In this way very complete protection is gained, except against such enemies as the whelk, which can bore a hole right through the shell (see p. 128). The foot may be compared in shape to an axe-head, hence the name Pelecypoda.[1]

These bivalves are all aquatic, and obtain their food merely from the current of water which they suck in; hence they have no need, either for protection or for purposes of nutrition, of active movements or of keen senses, and we find them generally living sedentary lives, often partially buried in the sand or mud at the bottom of the water. Correlated with this inactive life is the necessarily greater development of the respiratory organs (compare the case of sedentary and free-swimming *worms*), and at the same time the degeneration of the head with its sensitive tentacles and eyes. There is merely a mouth-opening in the front of the body, and no special head-lobe. The mouth contains no rasp, for none is needed where the food is not to be scraped from the surface of a solid object but swallowed whole.

[1] Greek, *pelekus*, an axe; *pous*, *podos*, a foot.

Freshwater Bivalve Molluscs

Type: **The Swan Mussel** (*Anodonta cygnea*).

The Swan Mussel is a large form common in the mud at the bottom of streams.

The Shell. The shell (Fig. 95) measures, when full grown, from four to six inches in length, two or three inches in breadth, and one to two inches through from one valve to the other at the thickest part. The sexes are

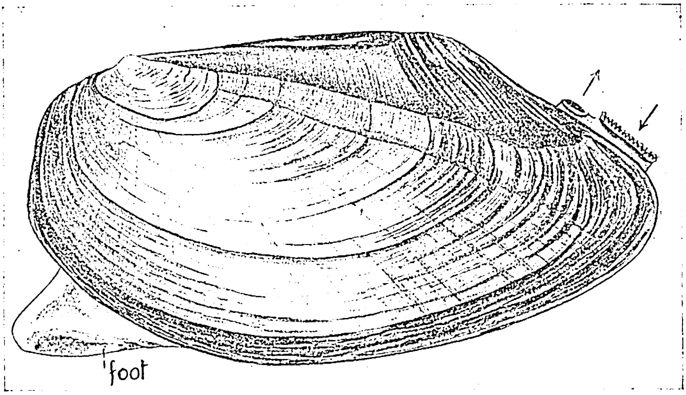

FIG. 95.—The Swan Mussel (*Anodonta cygnea*).

distinct, and they can be sometimes distinguished by the greater thickness from side to side of the shell of the female. The colour of the shell is a greenish-brown. It is marked with more or less concentric lines of growth, each line representing what was formerly the actual margin of the shell. Its size increases year by year until the mussel is twelve to fourteen years old.

The lower free margin of each valve of the shell is rounded, but the two valves meet above in an almost straight line, where they are united by an elastic ligament, narrow in front but broader behind. This is known as the *hinge-line*. At the anterior end of the hinge-line is the *umbo*, the oldest part of each valve. It will be seen that in the Swan Mussel the shell has grown unequally round this umbo, hardly any

shell substance at all having been formed above it, and much less in front than behind it, hence the very unequilateral form of each valve. In other genera of freshwater mussels the two valves are held together also by "hinge-teeth," of which there may be three pairs. One pair, close to the umbo, forms the *Cardinal teeth*, and two pairs, one in front and one behind the umbo, are known as the *Lateral teeth.*

If the shell is removed and its inner surface examined, it will be found to have a pearly white, more or less ridescent appearance, except round the margin. The struc-

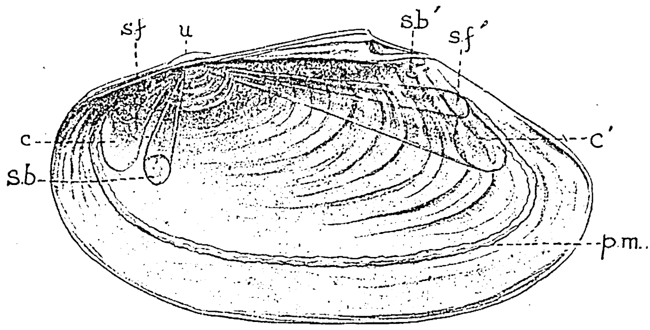

FIG. 96.—The Swan Mussel. Right valve of the shell from within.

u, Umbo; *c*, *c′*, scars of "adductor" muscles which close the shell; *sf*, *sf′*, scars of muscles which move the shell forwards; *sb*, *sb′*, scars of muscles which move the shell backwards; *pm*, the scar of the "pallial" muscle which attaches the mantle to the shell.

ture of the shell is essentially similar to that in univalve molluscs, consisting of the same three layers (see p. 114), but the nacreous layer is thicker here, whilst the margin of the shell consists of the horny layer alone, this being at first reflected round the edge of the shell as a narrow flexible fold. On the inner surface of each valve are certain marks which are due to the attachments of the chief muscles of the body.

The largest scars are those of the two important "adductor" muscles, which connect the two valves of the shell, passing right through the body (Fig. 96, *c*, *c′*); these by their contraction cause the closing of the shell. Two other pairs of scars (Fig. 96, *sf*, *sf′*, *sb*, *sb′*) are those of the muscles

which cause the forward or backward movements respectively of the shell and the movements of the foot which carry the body forward.[1] Faint tracks can be seen diverging from the umbo to the present position of these muscles, marking the paths along which their attachments have shifted as the animal grew.

Running parallel to the edge of the shell, and starting from the outer side of these special muscle scars, is another long thin scar where the muscles of the mantle were attached to the shell (Fig. 96, *pm*).

The pearly lining to the shell is deposited by the mantle in thin overlapping films, causing the surface to be very delicately ridged, and thus producing, by the play of light on it, the "interference colours" which give the beautiful iridescence characteristic of mother-of-pearl. This mother-of-pearl layer is much more developed in some of the marine mussels and in oysters.

Formation of Pearls. If any foreign object, such as a grain of sand, gets within the shell between it and the mantle, the irritation of its presence causes a special secretion of nacreous substance round the object, either merely covering it and cementing it to the shell, or in some genera—though not in *Anodon*—forming complete concentric layers round it, and so producing a *pearl*, or "shell-berry" as it used to be called.

In some instances it has been shown[2] that the pearl formation in marine mussels is due to the presence in the mantle tissues of a little parasitic worm, which whilst in its resting stage is enclosed by the mussel in a pearly prison, and so is usually destroyed. Even if the worm manages to make its escape, the formation of the pearl, having been begun, is completed. It is probable that this is the cause of the formation of the most perfect pearls—a curious case of the production of beauty resulting from a pathological stimulus; a more prosaic explanation, perhaps, but not less wonderful and interesting than the belief held by the ancients and quoted by Pliny, that pearls were drops of rain which had

[1] See discussion on locomotion in O. H. Latter's *Natural History*, 1904, pp. 166 and 170-173.

[2] Dr. Lyster Jameson in *Proc. Zool. Soc.* vol. i., Lond., 1902. Professor Herdmann, *Nature*, vol. lxvii., Apr. 30, 1903.

fallen into the shell when it was opened by the animal and were there transformed into pearls!

Most of our pearls are obtained from the large pearl oyster (*Meleagrina margaritifera*), which is common round the coasts of tropical countries (see page 158), but the freshwater mussel of North Britain (*Unio margaritifera*) also produces pearls of value.

The Body with Shell intact. Beyond the shell there projects, when the mussel is active, a large, fleshy, somewhat wedge-shaped "foot." When the animal is at rest, this foot, and often more than half of the shell, is buried in mud or sand, and there can only be seen the back of the shell, gaping slightly open, and exposing the thickened hinder edges of the mantle-flaps which bound two apertures—an upper, smaller, oval one, and, a little way below this, a vertical, slit-like opening round which the mantle-edge is pigmented and fringed with small tentacular processes. If a little carmine, or some other finely divided coloured substance, be suspended in the water, it can be clearly seen that there is a constant stream of water passing *into* the lower, inhalent aperture, and *out* of the upper, exhalent aperture.

Body with Shell removed. To understand the mode of nutrition and respiration in such a bivalve, it is desirable to remove one valve of the shell from a mussel and study the organs that are then exposed. For this purpose it is necessary to wedge open the valves with some strong object, such as a flat ruler, and then, with a penknife or scalpel, cut through the muscles on one side which attach the mantle to the shell (see Fig. 96), sliding the knife up carefully between mantle and shell so as not to damage the mantle. Bend back the valve thus separated and remove it, cutting through the ligament along the hinge-line. The soft body which is lying in the remaining valve of the shell will now be seen covered by the mantle-lobe of this side, and—in order to see the organs lying below—this must be turned back, or cut away along the line of attachment (Fig. 97, *lm*). Before this is done, however, the formation of the exhalent and inhalent apertures should be noted. The two margins of the mantle-lobes fuse just above the exhalent aperture, and then separate to form its opening, the lower limit of which is due, not to a second fusion of the mantle-lobes below it, but

merely to a nipping in of the mantle, so that the two margins are pressed closely together. The inhalent aperture is limited below in the same way. Further dissection and examination is best done under water.

Respiration. When the mantle-lobe on one side is removed, the so-called plate-like "*gills*" (Fig. 97, *g*) will be seen lying along the middle of the body above the foot which projects in front. There are four of these "gills," two lying on either side of the foot; they should be pushed aside one after the other, so as to expose those lying below; they have a spongy, porous texture, being formed of a very

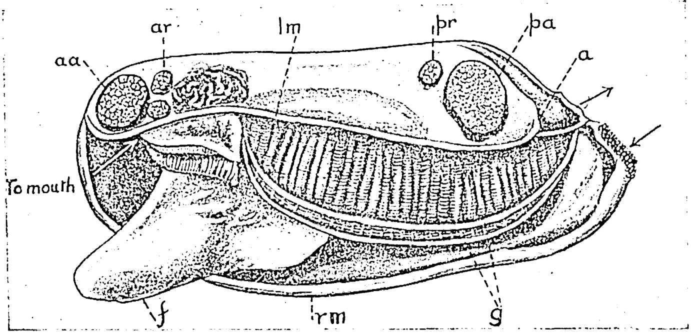

FIG. 97.—The Swan Mussel.

aa and *pa*, Muscles which close shell; *ar*, *pr*, muscles which move shell forwards; *lm*, cut edge of left flap of the mantle; *a*, anus; *f*, foot; *g*, "gills"; *rm*, edge of right mantle-flap.

complicated system of vertical and horizontal bars united into a kind of close trellis-work—the vertical bars causing the striation visible on their surface. These structures were called "gills" when it was thought that they had a respiratory function—a function probably performed by the mantle alone.

The impure blood from the foot and viscera is carried by special vessels first to the kidneys, and then to the mantle-lobes. The blood is purified by the oxygen in the water which enters by the inhalent aperture, washes over the inner surfaces of the mantle-lobes, over and through the gills, and finally passes into the cavity above the gills, and out of the exhalent aperture. This water current is maintained by the lashing of the hairs which cover the gills, but which can only be

seen under a microscope. The purified blood is carried by special veins to the right and left auricles of the heart, which lies in the cavity just above the gills; it can often be seen without further dissection through the transparent walls of this cavity. Thence the blood passes into the single ventricle and is distributed again to all parts of the body. The fluid is colourless, and hence the path of the circulation cannot be demonstrated without special injection and dissection of the vessels.

Nutrition. The same water current that carries to the mantle the oxygen necessary for respiration, carries also the microscopic organisms which serve the mussel for food.

The *mouth* of the mussel lies in front just above the foot, and is best found by probing with a "seeker" or blunt pin. On either side of the mouth lie two triangular palps having much the same appearance and texture as the gills; the outer palps unite over the mouth, forming the upper lip; the inner palps unite below the mouth, forming the lower lip. These palps, like the gills, are covered with lashing hairs or cilia. When the in-current of water passes through the gills, it leaves behind it all the organisms and solid matter suspended in it, which are too coarse to pass through the gill structure; thus a slimy rope of organic matter gradually accumulates in the groove between the two pairs of gills. This organic substance is passed forward between the palps by the action of the cilia, and onward into the mouth, whence it is driven in a similar way into the stomach and passed on into the intestine, the inner walls of which are lined with cilia. The intestine runs down from the stomach into the upper part of the foot, where it follows a curiously irregular course, coiling backwards and forwards, then turning upward and running right through the heart, and ending close behind the exhalent aperture. Any excreta are carried out with the exhalent water current.

The mussel seems to have, to some extent, the power of controlling the nature of the food substances which are allowed to pass in with the inhalent current; this is due doubtless to the sensitive tentacles which surround the inhalent aperture. When the approach of any undesirable substance is detected by these tentacles, a sudden exhalent discharge of water takes place from *both* apertures, driving the harmful matter away.

Reproduction. The sexes are distinct except in occasional abnormal cases; the sexual organ, ovary or spermary, lies in the visceral mass at the upper part of the foot, but only by making a microscopic examination can we tell, with certainty, which of the two is present in any one individual. The eggs are discharged from the ovary and are passed into the outer gills, which become in consequence very greatly distended, and are known as the "brood-pouches." The eggs in this position are fertilised by the sperm cells carried in by the inhalent water current. This takes place in the summer, and the development of the eggs goes steadily on within the brood-pouch until the following spring, the embryos being nourished all this time by a mucous substance secreted by the gills. Even by the autumn of its first year of life, the little embryo has reached what is known as the *Glochidium* stage, in which it has a bivalve shell with a sharp-toothed hook at the apex of each triangular valve (Fig. 98). Each valve is perforated by many minute pores. The shell is lined by a bi-lobed mantle which bears little sensory cells, and between the two valves of the shell runs a strong muscle, by means of which the shell can be closed. From a little papilla on this muscle projects a long, coiled, sticky thread, the *byssus*. In February or March, these Glochidium larvae are discharged from the brood-pouch, pass out into the water—usually in the exhalent water current—and are carried along by any current in the water outside; or they may sink gradually, often catching, by means of the byssal threads, on to some weed and then remaining supported in mid-water. Should a fish come near them, they become very much agitated, and clap the valves of their shells

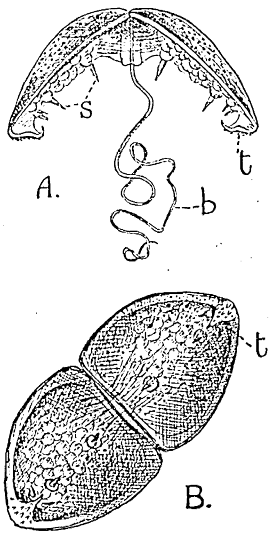

FIG. 98.

A, Glochidium of Anodon seen from the side; *b*, byssal thread; *t*, tooth at margin of shell; *s*, sensory papillae. *B*, Glochidium seen from below with shells gaping widely.

violently; this causes the byssus to extend more, and it may very likely catch on to the fish and stick, so that the fish swims off carrying a mass of glochidia with it. Then if any glochidium comes into actual contact with the fish—as it very likely would do as the fish darts about—it sesies the skin with the hooks on its shell and drags it in between the valves, causing such irritation that the tissues of the fish inflame and form a sort of case or "cyst" round the larva; in this position the larva remains for three months, living as a parasite, absorbing its food from the juices of the fish. A stickleback is often victimised in this way. The young mussel gains not only a temporary home and food, but also transport from one part of the pond to another. Meanwhile, the internal structure of the larva changes gradually to a structure similar to that of the adult; a new bivalve shell is secreted by the mantle below the glochidium shell, which, however, remains covering it for some time. The cyst formed by the fish finally withers and drops off, and the little mussel now at last begins its independent life, though for several weeks longer it still retains its larval shell; the teeth of this shell press against the margin of the new shell that is growing within, and often cause a distinct irregularity in the lines of growth at this point. (This irregularity is, however, more marked in *Unio* than in *Anodon.*)

When first it begins its independent life, the little mussel is not much larger than a pin's head and is very transparent, and, therefore, difficult to study closely, except under the microscope.

Each pair of mussels may produce hundreds of thousands of young.

Sense Organs and Senses. There is a fairly well developed nervous system, and all that part of the body which is exposed beyond the shell is more or less sensitive to touch and to light. The tentacles that surround the inhalent siphon seem to be organs of taste as well as of touch, but there are no other clearly differentiated sense organs.

Enemies of the Mussel. Mussels are eaten by several kinds of water-fowl, and sometimes also by otters and water-voles.

Other Freshwater Bivalves.

Unio. The genus *Unio* differs from *Anodon* in having strongly marked lateral hinge-teeth; also in having a depressed area in front of the umbo.

This genus is common in rivers and ponds.

Unio margaritifera is only found in rapid streams in the mountainous districts of the North of England, and in Scotland, Wales, and Ireland. It is this species which may produce valuable pearls.

Sphaerium, or "Orb-shell Cockle."

Orb-shell cockles are small forms with almost equilateral shells (*i.e.* with the umbo almost in the centre of the dorsal margin), and with distinct hinge-teeth, both "cardinal" and "lateral." The valves of the shell are so convex as to give the name "orb shell" to this genus.

The margin of the mantle, round both the exhalent and inhalent apertures, is drawn out into a short siphon (see Fig. 99).

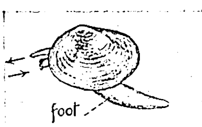

FIG. 99.—*Sphaerium corneum.*

Sphaerium corneum (the Horny Orb-shell) is very common in ponds and ditches. A full-grown specimen may be $\frac{1}{2}$ an inch long.

Sphaerium lacustre is also very common in England. It is rather smaller than the last, and more compressed.

Pisidium, or "Pea-shell Cockle."

In this genus the shell is smaller than in *Sphaerium*, and the umbo is no longer in the centre of the dorsal margin, but behind it. There is only one siphon, the exhalent siphon. The shell has hinge-teeth, as in *Sphaerium.*

There are several fairly common species; none have a shell more than $\frac{1}{3}$ of an inch in length, and the differences between them are not very marked.

Marine Bivalve Molluscs (*Oysters, Scallops, Cockles, etc.*).

Oysters.

The Common Edible Oyster (*Ostrea edulis*) is of economic importance, because of its popularity as an article of food.

Oysters, when adult, are incapable of locomotion. The little free-swimming larvae, which are liberated from the parent as "oyster spat," quickly disperse, and after a time each settles down on some hard surface, lying on its left valve, which quickly becomes cemented down, so preventing further movement. This valve becomes thick and deeply

concave, forming a basin in which lies the body of the oyster, covered by the thinner, flat upper valve, which can be lifted up or closed tightly like a lid. The foot is rudimentary in this sessile mollusc, which is entirely dependent for its food on the nutriment brought by the currents of water which wash over it. There are four gills.

The fringed margin of the mantle protrudes slightly from the shell, and on it are little pigmented masses which are sensitive to light. Only one pair of large muscles for closing the shell is present, situated nearly in the centre of the body.

The chief oyster-fisheries for edible oysters are to be found off the coasts of Europe, wherever the ground and the currents make a suitable habitat for them. The oyster farms at Whitstable spread over an area of more than 27 square miles—the oysters bred there, and others from on or near the Thames estuary, are called "Natives," and are said to have a greater delicacy than those bred elsewhere.

Oysters are hermaphrodite, though the ova and sperms do not ripen at the same time, and some authorities think that cross-fertilisation occurs. They reproduce in a wonderfully rapid way if they are protected. One individual, after its third year of life, may give rise to over a million embryo oysters. Nevertheless, owing to the many dangers to which they are exposed in their fixed lives, the death-rate amongst them is enormous. There must also be a large mortality amongst the embryos when first they escape, for they are then desirable morsels for any hungry mouth, and, even when full grown, oysters are attacked and devoured by whelk and star-fish, the former drilling a hole through the shell with its rasp and then sucking out the contents,[1] the latter destroying them in the way described on page 66; the parasitic sponge, *Cliona*, also bores into the shell, pitting it with tiny holes; the Skate, the Octopus, and Crabs are also dangerous enemies; there is need for many offspring if the race is to survive.

They grow slowly; at the end of the first year they are about 1 inch in diameter, and this measurement increases approximately by another inch each successive year, until they are six or seven years old; they may live ten years.

The breeding time is in the summer, and then, from

[1] See page 128.

the dealers' point of view, oysters are "out of season," or, in the familiar phrase, "oysters are in season only when there is an 'r' in the month," *i.e.* from September to April.

The Pearl Oyster (*Meleagrina margaritifera*) is found chiefly off the north and west of Australia. This oyster is valuable not only for its pearls, but also for the thick mother-o'-pearl lining to the shell, used in making buttons, brooches, and other ornaments. Some of the best pearls are obtained from a smaller species of pearl oyster found in the oyster banks off Ceylon, where they are collected by native divers.

Interest has been recently aroused by the work of the Japanese in producing "*culture pearls*" by an artificial stimulation of the Pearl Oyster. A tiny bead of nacre is cut from a newly opened oyster and is wrapped in a tiny sac of the living epidermis of its mantle, and this is then embedded in the mantle of a living unharmed oyster which is quickly returned to the sea for several years, it may be 6 or 7; then it will probably be found to have produced a pearl very difficult to distinguish from one naturally produced except by cutting a section of it, when the artificial centre will be disclosed.[1]

Mytilus. The Sea-mussel. The Sea-mussel (*Mytilus edulis*), though not always wholesome, is also cultivated for food, especially off the coasts of France. It is this species which is found in countless numbers attached to piers or any pieces of wood submerged in the sea. The narrow shells have two equal valves, are from one to three inches long, and of a beautiful slate-blue colour. Sea-mussels can move freely on their long, narrow, fleshy foot, but can also fix themselves by a number of threads which form the organ of attachment known as the *byssus* (cp. Fig. 98). Each thread is secreted, from a gland in the foot, as a very fine viscid string which hardens in the water.

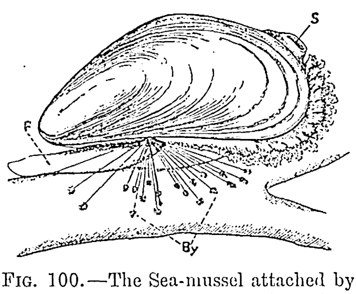

FIG. 100.—The Sea-mussel attached by its byssus, *By*, to a piece of wood. *F*, foot; *S*, anal siphon.

[1] See Dr. Jameson's paper in *Nature*, May 1921; also article by H. Onslow in *Conquest*, Feb. 1922.

Pinna. The Fan Mussel. The Fan Mussel (*Pinna fragilis*) is the largest British bivalve, the shell being sometimes a foot long; it buries the pointed end of the shell in the sand or mud and fixes itself with a very strong silky byssus, the threads of which have at times been woven into articles of clothing.

Solen. The Razor. The Razor Shell (*Solen* or *Ensis*) burrows vertically into the sand, and when covered with water the two short siphons open on the surface of the sand looking rather like a keyhole. If alarmed the creature squirts a jet of water from its siphon and sinks deep down in its burrow.

Cardium. The Cockle. The Common Edible Cockle (*Cardium edule*) lives buried in the sand or mud, often above low-water mark, with its two short respiratory siphons projecting just out of the sand into the water. Although it lives, on the whole, such a retired life, the cockle can leap freely over the surface by means of its large curved foot.

Pecten. The Scallop. Scallops are perhaps even better known than cockles on account of their ornamental shells, which are fluted and prettily coloured, red and yellow. The lower, right, valve of the shell, on which the creature rests when adult, is deeply concave, the upper valve is flat. The young scallops can swim freely by the alternate sudden opening and shutting of their shells. The Common Scallop (*Pecten maximus*) is often to be seen in the fishmonger's shop, where the bright orange colouring of the foot makes it a conspicuous object. The margins of the mantle are fringed with white tentacles and set with many little shining coloured eyes, which have an elaborate structure, recalling that of the vertebrate eye.

Classification of the Bivalve Molluscs mentioned in Chapter XI.

Family 1. Unionidae (Freshwater Mussels).—Foot long, compressed, without byssus; no siphons present.
Unio margaritifera, the Pearl Mussel.
Anodon cygnea, the Swan Mussel.

Family 2. Sphaeriidae (Freshwater Cockles).
Sphaerium, the Orb-shell.
Pisidium, the Pea-shell.

Family 3. Ostreidae (Oysters).—Shell fixed by one valve, no byssus, rudimentary foot, no siphons.
Ostrea edulis, Edible Oyster.
Margaritifera vulgaris, Ceylon Pearl Oyster.

Family 4. Mytilidae (Sea-mussels).—Symmetrical shell, numerous long byssal threads.
Mytilus edulis, the Sea-mussel.

Family 5. Aviculidae.—Foot long, with byssus, no siphons.
Pinna fragilis, the Fan Mussel.

Family 6. Solenidae.—Foot powerful, no byssus, short siphons.
Solen Ensis, the Razor Shell.

Family 7. Cardiidae (Cockles).—Much-folded gills, long bent foot, byssus present, short siphons.
Cardium edule, the Common Cockle.

Family 8. Pectinidae (Scallops).—Ribbed shell, byssus absent or rudimentary, mantle-edge possessing "eyes" and little tentacles.
Pecten maximus, the Common Scallop.

PRACTICAL NOTE ON BIVALVES

The *Freshwater Mussel* is a useful and hardy inmate of a tank such as that described at the end of Chapter IX. It should always be given some sand on the tank bottom, in which it can bury its foot. It will then hold its body sloping obliquely up, with the front end close to the ground and the hind end much higher, and with the inhalent and exhalent apertures open for the passage of water in and out.

Its use in the tank consists in the current it causes in the stagnant water, and also in the fact that it takes in and digests any little particles of dead organic matter that may be floating in the water. To provide it with plenty of fresh microscopic food, a bunch of fresh weeds from a pond should sometimes be dipped into the surface water and shaken.

Sketches should be made (1) of the external view of the mussel when actively feeding, so that the exhalent and inhalent apertures show, and also the foot by which it fixes itself; (2) of the internal organs as displayed in a dead mussel when one valve of the shell and one flap of the mantle have been removed; (3) of a glochidium larva seen under the microscope; these can be obtained from the outer gill of a female mussel any time during the autumn; the movements of the little larvae are interesting to watch.

Marine Bivalves do not thrive in a small tank.

CHAPTER XII

PHYLUM X.: MOLLUSCA (*continued*)

Class III.: CEPHALOPODA

(HEAD-FOOTED MOLLUSCS)

General Characteristics. THIS class contains, amongst other strange forms, the Cuttle-fish, the Squid, the Octopus, the Argonaut, and the Pearly Nautilus. They are all sea-dwellers, and all, except the Nautilus and the Argonaut, have naked bodies, though a rudimentary calcareous or horny shell may be hidden away within the fleshy "mantle" which wraps round the soft, elongated body. The head projects at one end; it bears large well-developed eyes, and a mouth surrounded by eight, ten, or many fleshy tentacles, each of which usually bears many suckers. The number of tentacles is characteristic of the Octopods, the Decapods, and the Nautilus respectively; in origin they are homologous with the foot of a snail or mussel, and so the class gets its name of *Cephalopoda* or "Head-footed."[1]

The mantle is fused with the body except on the ventral side; here a sac-like space is left between it and the body; in this space are lodged the two (or in Nautilus the four) gills, and from it protrudes the funnel (see Fig. 101).

Respiration. Water is drawn in through the slit-like aperture between the free mantle-edge and the funnel; this washes over the gills and aerates the blood in them; it is then discharged through the tubular funnel, together with any excretory matter which has passed into the funnel from the anus which opens within its base.

[1] Greek, *kephale*, head; *pous*, *podos*, a foot.

Movement. The water from the funnel can be expelled with such force that the recoil drives the body rapidly in the opposite direction to that of the escaping liquid. Indeed this is the normal method of effecting movement.

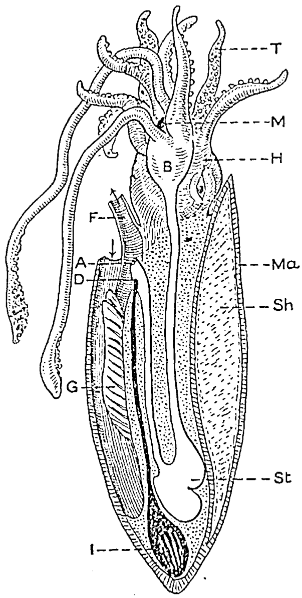

FIG. 101.—Section through a Cuttle-fish (diagrammatic).

H, head; *M*, mouth; *T*, tentacle; *B*, mouth muscles and jaws; *St*, stomach; *I*, ink-bag; *D*, opening of ink-duct; *Ma*, mantle; *Sh*, shell; *G*, gills; *A*, anus; *F*, funnel.

The Ink-bag. In all Cephalopods except Nautilus, the discharged water can be blackened by an inky fluid given out by a special gland opening into the funnel (Fig. 101, *I*). The inky cloud so produced is of great value in hiding the creature from any pursuing enemy.

On the ground, Cephalopoda creep slowly along head downwards, holding on by the many small but powerful suckers with which (except in the case of the Nautilus) their tentacles are plentifully supplied.

Order: DI-BRANCHIATA

Sub-order 1: OCTOPODA

The Octopus. *Octopus vulgaris* or "Poulpe" is perhaps the most unsightly of all creatures, at any rate when seen out of the water, though when in his native haunts he must have a certain beauty of his own as he sits with his eight curling tentacles drooping all round him, and his large eyes brightly gleaming (see Fig. 102). When at home he lives under the sea, alone in a crack or crevice of a rock or under the shelter of a boulder, holding on firmly with two or three of his arms whilst the others hang limply in the water. He is nearly invisible to passers-by, for he can change his colour and roughen and wrinkle his skin to match his environment, but he himself is keenly on the watch for any unwary creature—it may be a large fish, a lobster, or crab—and the moment one comes within reach, out dart the

arms and seize their victim in a relentless grasp, drawing it to the mouth, where it is rapidly scrunched up by the strong parrot-like beak. Occasionally the lurking place of an octopus is uncovered at a specially low spring tide, and close to one such "den" off the coast of Herm (Channel Islands) a heap of over 2000 empty shells showed how successful had been this

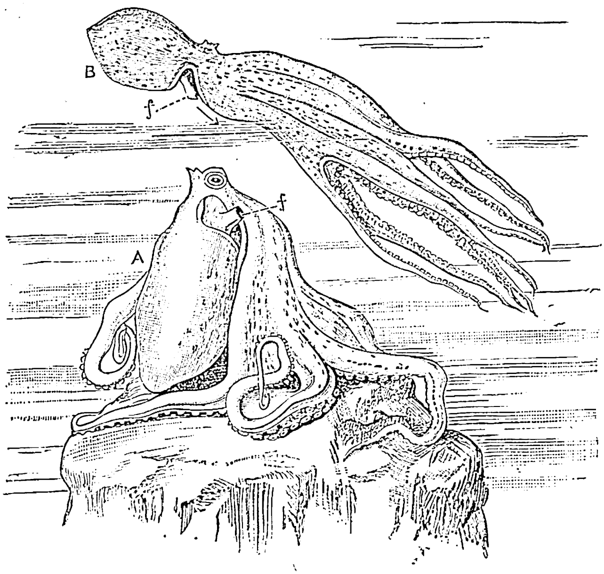

FIG. 102.—*Octopus vulgaris*, Naples.

A, at rest; *B*, in motion; *f*, funnel, the arrow showing the direction of the propelling current of water. (After Merculiano.)

means of "hunting." Each arm bears two rows of suckers; each sucker is a little sessile fleshy cup with a central muscular "piston" which can be withdrawn at the will of the creature, so causing a vacuum, if the sucker is first pressed against any surface. The resultant suction is so great that the whole tentacle may be torn away before the suckers will yield; but such an injury is not serious, a new tentacle will grow.

In swimming, all the tentacles are stretched out in front of the mouth as in Fig. 102, *B*.

Reproduction. The eggs are like hundreds, sometimes thousands, of tiny berries clustered round a central string. They are watched over by the mother and washed with jets of water from her funnel, until from each there hatches a tiny octopus, no bigger than a flea, which can at once swim actively in the water.

Octopus vulgaris is fairly common round our coast, and small specimens come in with the fishermen's hauls; after rough weather large specimens with arms 4 or 5 feet long have been washed up, but these are unusual; they are known more commonly in the Mediterranean Sea, where they are much dreaded by bathers.

The *Lesser Octopus*, with only one row of suckers on each arm, is not uncommon.

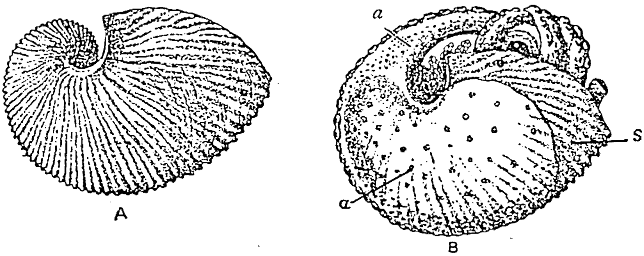

FIG. 103.—*A*, Empty shell. *B*, Female Argonaut withdrawn into shell. *a—a*, Arm; *s*, shell projecting from under the arm.

The Argonaut. The *Argonaut* or *Paper Nautilus* is a foreign Octopod, of which the beautiful delicate white shell is far better known than the creature itself, for it is rarely captured alive. It is about 7 inches across and is spirally coiled; each side is covered with radiating ribs, the ends of which form a double row of projecting knobs down the convex surface.

This shell does not correspond to the shell of any other mollusc, for it is a special structure formed only by the female Argonaut as a cradle for her eggs, and it is secreted, not by the mantle, but by the specially enlarged and flattened posterior pair of arms (Fig. 103, *B*, *a*) which hold it in position round the body, to which it is not attached by any muscle. The creature seems to float along in a boat of her own making, with the incurved, narrow end of the shell uppermost and all

her other six arms floating out on all sides, though she can withdraw them into the shell if alarmed, as shown in Fig. 103, *B.* If rapid movement is desirable she darts backwards as shown in Fig. 104.

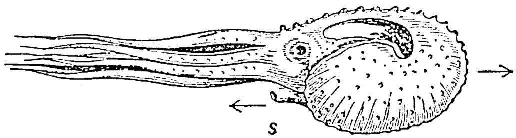

FIG. 104.—Female Argonaut swimming (reduced). *S*, funnel. Arrow behind shell shows direction of movement.

The male Argonaut is only about ½ inch long, and is more like the common octopus, for its arms are all alike except for one special one which, as is the case in all two-gilled Cephalopods, is modified to form a receptacle for the sperm cells. At the time of mating (copulation) the whole tip of this arm, known as the "hectocotylus," is, in Argonaut, transferred to the female, but this is not so in most genera.

Sub-order 2: DECAPODA

The "Ten-armed" Cephalopods include the true Cuttle-fish (*Sepia*), the Squid (*Loligo*), and *Spirula*.

General Characteristics. The two additional arms of these forms are much longer than the others and arise from within the circle of the short arms; they have suckers at their tips only and can in most cases be retracted into pouches; they are used to catch their prey and pass it down to the shorter arms which carry it to the mouth to be torn and rasped to pieces by the jaws and tongue.

There is an internal shell under the mantle; this is horny in the "*Squid*," where it is known as the "pen," and calcareous in the case of the so-called "bone" of the Cuttle-fish.

Down each side of the body there is a fold of flesh known as the "fin," which is used in swimming.

The Cuttle-fish (Sepia). The Common Cuttle-fish (*Sepia officinalis*) may be found between tide marks at the breeding season, though at other times it inhabits deeper water. Alive it is a beautiful object swimming in the sunny shallow waters, changing colour as it moves with the rapid

jerky movement characteristic of its kind, ejecting water spasmodically from its funnel and at the same time alternately spreading and closing its arms so as to drive a current of water forward and accelerate the backward movement of the body.

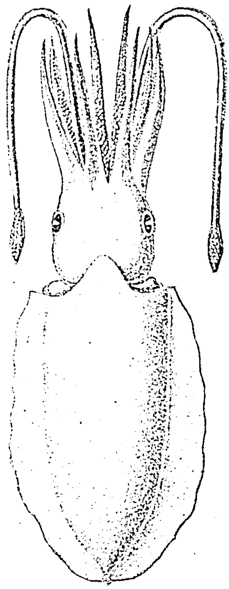

FIG. 105.—A Cuttle-fish (*Sepia cultrata*) seen from above.

Like the Octopus, it lurks hidden at the sea bottom to watch for its prey, catching it with its terrible tentacles, each of which is beset with four rows of shortly stalked suckers.

Sepia ink. The "ink-bag" of the *Sepia* produces plentifully an intense black fluid which long ago was used as a writing medium, and still the "sepia" of the artist is obtained from it. It is a wonderfully indestructible pigment, and it is stated by Dr. Buckland that in fossil Mollusca, allied to the modern *Sepia*, some of it has been found still able to produce excellent "sepia," although it must be thousands of years old.

The "Cuttle-bone." The white "cuttle-bone" consists of a number of calcareous laminae; it has a thin horny margin round it, and a little spine below called the "rostrum." It is used for polishing wood and other purposes, and its value as bird food is well known. One of the largest cuttle-bones ever found was $1\frac{1}{2}$ feet long.

Eggs. The eggs look like small black grapes attached, some fifteen or twenty together, to a stem of sea-weed—"Sea-grapes" the fishermen call them.

The Squid (Loligo). The *Squid* or *Calamary* is very like the Cuttle-fish in general structure and shape (see Fig. 106), but the internal shell is *horny*, and it is known as the "pen," from its resemblance to a quill pen.[1]

Squids are met with all round the British coast. They are remarkably active creatures, going about in shoals at certain seasons and occasionally leaping right out of the water as

[1] Latin *calamus*, a pen.

they dart through it in pursuit of their fish food. Sailors sometimes call them "sea-arrows" or "flying squids." Their milk-white, semi-transparent bodies assume lovely red tints when they are alarmed.

Size. They have been captured of surprising size, varying from 32 to 52 feet, total length; the largest are taken off the coast of Newfoundland; they are formidable creatures indeed and have given rise to many fabulous stories, as well as to well-authenticated ones, of terrible encounters between divers and these monsters of the sea.

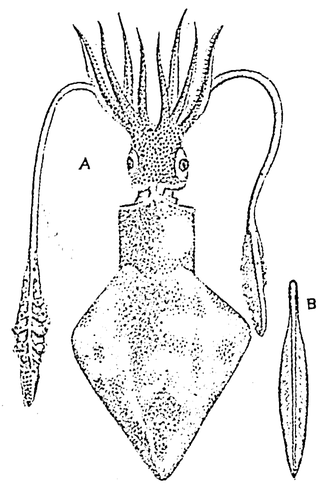

FIG. 106.—*Loligo vulgaris.* *A*, Entire animal, dorsal view; *B*, horny internal shell or pen. (From Keferstein.)

Eggs. The eggs of a Squid are deposited in gelatinous semi-transparent cases, each 1 to 4 inches long and ½ inch wide, and each containing over 200 eggs. Hundreds of these egg-cases are attached together in a radiating, mop-like bunch.

Sepiola. *Sepiola* is a little Squid with a horny "pen" which is common on the British Coast, and is often caught in the nets of shrimpers. Its body varies from ½ inch to 4 inches long, and it buries itself up to the eyes in the sand, blowing a hole in the sand by directing jets of water from its funnel into the desired spot until enough sand is washed away, stones too big to be thus dislodged being picked up and removed by the suckers on the arms.

Spirula. Until quite lately *Spirula* has been a very little known creature, for only a very few specimens had been captured. However, during the recent Dana Expedition many were taken alive in the North Atlantic, and some accounts of their structure and habits have now been published.[1]

[1] See "Live Specimens of Spirula," by Dr. Johs. Schmidt, in *Nature*, 9th December 1922.

The beautiful little pearly-white, loosely-coiled shell has long been well known, for it is abundant on some tropical shores, and is occasionally thrown up on our own coasts, the Gulf Stream sometimes carrying it to Tenby.

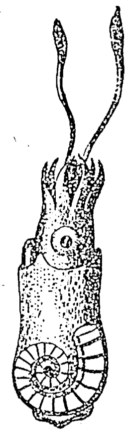

FIG. 107.—*Spirula*. From *Brit. Mus. Guide.* Lateral view (diagrammatic. Mantle lobe drawn as if transparent, to show shell).

This shell lies vertically within the body (see Fig. 107), it is nearly entirely covered by two reflected lobes of the mantle, but projects externally along the dorsal and ventral margins. When cut in halves longitudinally it is found to be divided into many chambers by transverse curved partitions, each one pierced by a slender tube, the "*siphuncle*" (see p. 170), running near the inner curve of the shell, and following its coils.

The number of chambers varies with the age of the creature. A specimen with mantle length about $\frac{1}{2}$ inch may have sixteen chambers, another with mantle length three times this may have thirty-five chambers.

The shell may be full of gas; in any case it seems to cause the posterior part of the body to float uppermost, the head and arms hanging down vertically.

The mantle has a rough whitish surface with some rust-red lines and bands. At the posterior end (uppermost when at rest) are two semi-circular fins with a circular disk between them bearing a little bead-like light organ which continually gives out a pale yellowish-green glow.

The creature seems to live thus, suspended some 300-500 metres below the surface, occasionally darting here and there, guiding its motion by changing the direction of the funnel through which the jets of water are driven.

The Belemnites. The fossil Belemnites which are so plentiful in rocks from the Lias to the chalk, looking rather like the pointed end of a very thick slate-pencil, are thought to be the fossilised outer "guard" of the internal shell of a creature near akin to *Spirula*, though the shell is no longer spirally coiled. When perfect, it has at the broader end a simple conical part which is divided by transverse lamellae; this is known as the "phragmocone." This is

the part that is thought to correspond with the whole of the shell of *Spirula*, but to have been replaced mainly by calcareous laminae in the Cuttle-bone. The narrower, more solid part, known as the "guard" or "rostrum," which forms the usual fossil is represented by a little downwardly pointing spine at the base of the Cuttle-bone, but there is nothing which corresponds with it in *Spirula*.

In some Belemnites the outline of the ink-sac can be recognised.

It is thought that these creatures were very like Squids, and that they lived, many together, on the muddy bottoms of shallow seas.

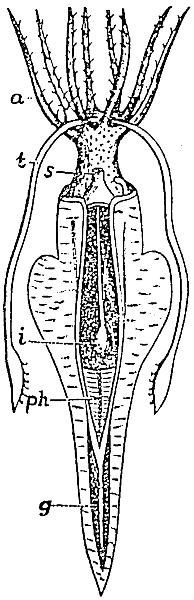

FIG. 108.—Diagram to illustrate structure of a Belemnite.

a, Tentacle; *s*, funnel; *i*, ink-bag; *ph*, phragmocone; *g*, guard; *t*, long tentacle.

Order: TETRA-BRANCHIATA

The Pearly Nautilus. Unique amongst the Cephalopods is the *Pearly* or *Chambered Nautilus* (*N. pompilius*) which inhabits the seas bordering on the Malay Archipelago. It is the only living representative of the four-gilled Cephalopods. It is unlike the two-gilled forms in having a true external shell, and many small retractile tentacles devoid of suckers and arranged in two whorls; it is devoid also of an ink-sac.

The Shell. The calcareous shell is spirally coiled, each new turn of the spiral surrounding the one before and being in close contact with it. It is white in colour, barred across irregularly with zebra-like stripes of yellow-brown.

The coil of the shell is in the opposite direction to that of *Spirula*, but its cavity is similarly divided by curved transverse septa into a number of chambers; the last of these is by far the largest of them all, and it is in this alone that the body of the creature is lodged, and into which it can be entirely withdrawn for protection. The smaller, now empty chambers are those discarded by the creature as

it outgrew them. An extension of the body, in the form of a tubular prolongation of the mantle, passes through a little hole in the centre of each septum, and coils with the coil of the shell. This tube is called the *siphuncle*; its function is not certain; possibly some gas passes along it from the body to lighten the burden of the heavy unused portion of the shell. It is known that these chambers are filled with a gas rich in nitrogen, and doubtless this has a hydrostatic function.

The shell has a most beautiful pearly lining covering not only the side walls, but also the overarching vault of each chamber. It was the contemplation of this shell that stirred Oliver Wendell Holmes to write his poem, "The Chambered Nautilus,"[1] one verse of which runs thus:

> Year after year beheld the silent toil
> That spread his lustrous coil;
> Still, as the spiral grew
> He left the past year's dwelling for the new,
> Stole with soft step its shining archway through,
> Built up its idle door,
> Stretched in his last-found home, and knew the old no more.

The Body. In the living creature when fully expanded there can be seen beyond the shell the head with its large lateral eyes and many tentacles, which, if it is swimming, are stretched out in front of it; dorsally the head is covered by a fleshy hood (Fig. 109, *h*), whilst reflected over the coil of the shell, covering the black portion of it, is a whitish fold of the mantle (this has been detached from the shell in Fig. 109). The hood is coloured brown, mottled with red, brown, and yellow, with little white warts on it; the head below is opaque white like the shell.[2] The body and shell together are said to be very difficult to see in shallow water, their coloration being lost in the play of light on the surface ripples of the sea;[3] when the body retracts, the hood entirely closes over the opening of the shell, shutting the creature in. Though Nautilus can swim actively, it is a ground feeder, creeping about on the floor of the ocean, devouring Crustaceans and Molluscs. It is occasionally seen on the

[1] *The Autocrat at the Breakfast Table.*

[2] "Notes on Living Nautilus," Bashford Dean, 1901, *Amer. Naturalist*, xxxv. pp. 819-837.

[3] A. Willey, *Zoological Results*, pt. vi., 1902.

surface of the water, specially after a storm, but this is not its normal haunt.

Fossil Nautiloid Forms. Shells of the Nautilus type are common in the Palaeozoic rocks. They vary a good deal. Some of them have spirally coiled shells with all the coils in contact like the modern forms; in some (*e.g. Gyroceras*) the spiral is loosely coiled so that the coils do not touch; in others again the coiling is very slight or the shell may even be straight (*e.g. Orthoceras*); but, in all, the septa are simple concave plates pierced by the "siphuncle."

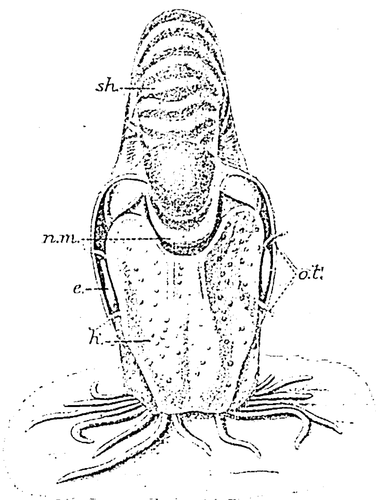

FIG. 109.—The Pearly Nautilus.

sh, Shell; *n.m*, mantle fold detached from coil of shell; *h*, hood; *e*, eye; *o.t*, ophthalmic tentacles.

Orthoceras chinense is the "Pagoda Stone," so called because of the old legend which maintained that it was formed underground wherever the tower of a pagoda cast its shadow. This beautiful fossil shell may be a yard long and four inches across its broadest end.

Nearly all these shells, however, disappear after the Palaeozoic times. *Orthoceras* survived until the Trias and then this too became extinct, and Nautilus alone remains to the present day to represent the family. Fossil shells identical with those of the living Pearly Nautilus have been found plentifully in the London clay of Highgate and Hampstead.

Ammonoid Forms. In the Liassic rocks are found quantities of fossils of coiled chambered shells like the Nautiloid forms but with much more complex partition walls or septa, though the lines of junction may be hidden under the outer layer of shell and only show if this is removed (see *S* in Fig. 110). Also in most of them there is a plate

which in the fossil closes the mouth of the shell. These fossils are the well-known "*Ammonites*" and they occur from Liassic rocks, at the base of the Jurassic, to the chalk, after which the genus appears to have become extinct.

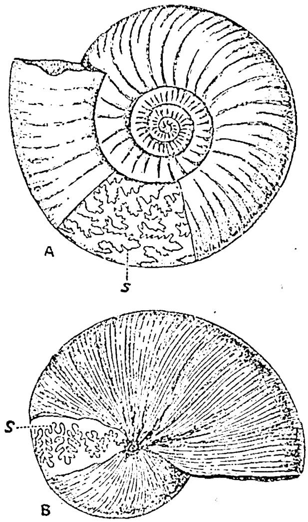

FIG. 110.—*A*, *Ammonites*; *B*, *Phylloceras*.

s, Lines of junction.

They vary in size from under an inch in diameter to the size of a cartwheel. Though in the genus *Ammonites* itself all the whorls of the shell are in contact, and all are exposed to view (Fig. 110, *A*), in some allied forms the coils are very loose and not all in contact, and in others the inner whorls are concealed by the outer as in *Phylloceras* (Fig. 110, *B*).

The fossils called by quarrymen "*Snakestones*" are casts of *Ammonites*. The interior of the shell has become filled up with calcareous matter and then the shell and septa have dissolved away, leaving the casts of the separate chambers looking rather like a string of very intricate vertebrae.

Classification of the Cephalopods mentioned in Chapter XII.

Order DI-BRANCHIATA. Those with two gills only.
  Sub-order 1. **Octopoda**. With eight tentacles.
    Octopus, Argonaut.
  Sub-order 2. **Decapoda**. With ten tentacles, two larger than the others.
    Cuttle-fish, Squid, *Sepiola*, *Spirula*.
    Fossil forms: *Belemnites*.
Order TETRA-BRANCHIATA. Those with four gills.
    Pearly Nautilus.
    Fossil forms: *Gyroceras*, *Orthoceras*, *Ammonites*.

CHAPTER XIII

PHYLUM XI.: ARTHROPODA OR JOINTED-LEGGED ANIMALS (*e.g.* LOBSTERS, CRABS, SPIDERS, AND ALL INSECTS)

Preliminary Note.

Amongst the lower groups of animals, we have noted various means of protection against the two chief classes of danger to which they are exposed: danger from the violence of the dashing waves in the case of those forms living between tide-marks in the sea, and the more widespread danger, occurring in all habitats, of the attack of enemies desirous of devouring anything edible. Some forms seem to flourish owing merely to the simplicity of the demands they make on their environment, and their enormous powers of reproduction and regeneration, as in the Protozoa and Hydroid Polyps. Others, such as earthworms, slugs, and snails, escape danger, to some extent, by living in sheltered places and by their cautious habits. The sessile sea-anemones avoid the danger of the violence of the waves by their power of contracting into a solid, resistant lump, and escape their enemies through possessing stinging cells, which make them undesirable as food. Bivalve Molluscs and most Echinoderms survive owing to the secretion by them of a hard protective coat, which either entirely covers their soft body at all times, as in the starfish, or into which the soft body can be withdrawn, as in the mussel and oyster. All such protective shells, however, such as those of the Molluscs, impede motion, and at the same time leave quite unprotected, when in use, the organ of locomotion, the muscular foot.

The animals of the next group to be considered, the Arthropoda, are segmented like the worms, and are bilaterally

symmetrical, but unlike worms their many pairs of legs are well developed and jointed, and each of these, as well as the head and body, is protected by a hard, horny, and calcified sheath or shell secreted by the skin below. This shell is known as the *exo-skeleton*, and is peculiar in being jointed with each joint of the legs, and in its segmentation over the body wherever the need of bending renders such a segmentation advantageous, the skin between the segments being left soft and uncalcified. In this way the whole body is efficiently protected, and at the same time the legs are strengthened and so can not only support, but readily carry along, a much larger body than is possible in less specialised animals. Hence we find amongst those Arthropods such as the crabs and lobsters, in which the protective shell is most strongly developed, that the creatures reach a very considerable size and yet can move rapidly.

Exo-skeleton.

The different mode, however, in which the shell is formed, and its increased complexity, are correlated with a disadvantage that does not occur amongst the Mollusca. A snail keeps the same shell throughout life, merely adding to the margin of it to meet the requirements of its growing body. In an Arthropod such a simple method of increasing the size of the shell is not possible, for it has been secreted from the whole skin below, and is a dead product which, when once formed and hardened by exposure to the air, is incapable of growth or even of extension. When, therefore, the shell gets too tight for the body within, it is burst and thrown off entirely, and the soft-bodied creature, which is now exposed, expands rapidly, before the new shell, which has been secreted below the old one, has had time to harden. Such a moult or *ecdysis* takes place periodically at fairly frequent intervals in those Arthropods which have thick calcareous shells and which increase in size for several years. Professor J. A. Thomson says of the Crayfish that "the moults occur in the warm months, eight times in the first year, five in the second, two in the third, after which the male moults twice and the female once a year, till the uncertain limit of growth is reached."

Moult of Shell, or Ecdysis.

During the moulting period the animal is very defenceless, and this time is usually spent in seclusion in some retired spot. In Arthropods of the Insect type, where the "shell"

is merely a horny transparent skin, the moult still occurs at intervals; it is probable that the reason for this is not merely the need of rendering possible the growth of the body, but that the process is also physiological, being the means by which certain waste products of the body are eliminated.[1]

General Arthropod Characteristics. The Arthropoda form a very large group, all alike in their bilateral symmetry and in having a segmented, chitinous, and calcified exo-skeleton enclosing the soft, boneless body. They all show a more or less marked segmentation of the body externally. Each segment bears a pair of the typical jointed legs which give the name to the group (*arthros*, a joint; *pous*, a foot). In nearly all Arthropods the mouth is surrounded by a number of curious little structures known as the *mouth parts*; the development of these shows that they are merely the ordinary jointed limbs or appendages of the fused segments of that region, modified for the purpose of catching food. Also on the head there are, except in spiders, one or two pairs of jointed *antennae*, which again represent modified limbs. A body cavity is present, but this contains blood, being a development of the vascular system and not a true coelom.

Nervous System. The external segmentation of the body is correlated to some slight extent with a corresponding repetition of the internal organs. This is shown in the main nervous system, which consists of a series of double ganglia, corresponding with the segments of the body and connected by a double nerve cord. This cord with its ganglia lies on the ventral side of the body, but in front it divides and passes round the gullet to the dorsal side, and there terminates in a specially well developed double ganglion, from which nerves go to the eyes and antennae. This dorsal ganglion constitutes the *brain*. The resemblance of the plan of the nervous system to that of Annelids is noticeable.

Circulation of Blood. There is a single heart, having a single cavity. It lies just above the alimentary canal, and by its pulsations it propels the blood throughout the body, but the circulation and aeration of the blood are slow, and its temperature therefore low, so that Arthropods are all "cold-blooded" creatures, *i.e.* their temperature varies with

[1] *Cambridge Natural History*, vol. v. p. 169.

that of their environment. This fact explains the great increase in activity noticeable in them in warm weather, and when the sun shines on them.

Respiration. The means by which the blood is aerated varies according to the habitat of the different Arthropods. Crustaceans (crabs, lobsters, etc.) live always in the water, and therefore need the respiratory organs termed *gills*, which are adapted for the purpose of obtaining oxygen from that dissolved in the water. Arachnids (spiders) and Insects, on the other hand, either live on land, or, if in water, come to the surface to breathe, and they all have special air-tubes or *tracheae* which carry the air to all parts of the body (see pp. 205, 234).

Development. Most Arthropods undergo a more or less extensive metamorphosis, *i.e.* from the egg there hatches a little form very unlike the adult parent of the egg, and this young form or *larva* develops by definite stages into the adult form, the metamorphosis being accompanied by frequent moultings of the inelastic chitinous skin.

Origin of Arthropods. This group of Arthropods is on the whole so very sharply marked off from any of the other groups of animals, that it was long before a link connecting it with any other was recognised. This link is

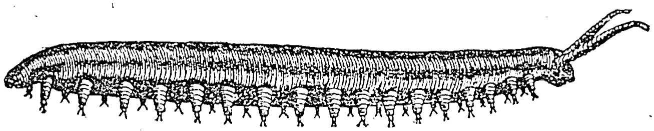

FIG. 111.—*Peripatus capensis.* (After Balfour.)

now found in the beautiful little creature *Peripatus*, of which several species are known in various tropical and southern countries, and which combines in a curious way both Annelid and Arthropod characteristics. It has an elongated, vermiform body which is not apparently segmented either externally or internally; it is covered by a thin, velvety skin, coloured a rich dark green, or blue grey, or orange red above, and flesh-coloured below; there are two unbranched antennae on the head, two jaws, one each side of the mouth, and also a pair of little papillae on the head from which the creature can

eject slime when irritated, or possibly it shoots this slimy jet over some small insect on which it desires to feed.[1] The eyes are simple, like those of worms rather than of Arthropods. Behind the head there project, from the lower side of the body, a number of paired appendages, on the end of each of which is a pair of small claws. These legs, at first sight, appear jointed, but the visible rings do not mark true joints. In the structure of its heart *Peripatus* resembles an Arthropod, and it breathes by tracheae, as do all the air-breathing Arthropods; and yet, on the other hand, there is within the body a series of paired excretory organs recalling those of Annelids, and this resemblance becomes much more striking when we trace their development, for it then becomes obvious that they, together with the single pair of reproductory organs and ducts, represent all that remains of a segmented coelom which is clearly present in the embryo *Peripatus*, as it is in the adult worm; indeed, at one stage of its development the young *Peripatus* is very like a young worm. The young are viviparous, thirty or forty being born in close succession. The continuous body-cavity which is conspicuous in the adult is developed from the blood-vascular system as in Arthropods.

Peripatus may therefore be looked upon as a real link between the air-breathing Arthropods and the Annelids, its connection being rather with the Myriapods (p. 224) and the Insects than with the Arachnids, which probably had a different origin, as did also the Crustacea.

Class I.: CRUSTACEA

(Crabs, Lobsters, Shrimps, Water Fleas, etc.)

General Characteristics. Crustacea are aquatic Arthropods breathing typically by gills. These gills are thin-walled, tubular processes from the body, through which the blood circulates and is thus brought into close contact with the surrounding water and its dissolved oxygen, the necessary interchange of gases for purifying the blood taking place by diffusion through the delicate membrane covering the gills. In some of the simpler forms only, gills are absent, the interchange of gases taking place over the general body surface.

[1] *Camb. Nat. Hist.* vol. v. p. 9.

The limbs of Crustacea, with the exception of the first pair of antennae, have typically two branches arising from the 2nd basal segment, a characteristic peculiar to them amongst Arthropods. In the adult of some forms some unbranched limbs may be found, but these have arisen as a modification of the two-branched structures found in the young.

Higher Crustacea (Malacostraca)

In the higher Crustaceans, a definite and constant number of segments and appendages occurs, namely, twenty segments and nineteen pairs of appendages, the last tail-segment alone bearing no appendages. In these higher forms, however, the segments of the head and thorax are difficult to distinguish, for, dorsally at any rate, the separate segments of the exo-skeleton are fused into one shield-like piece covering the back and hanging down laterally. This dorsal shield is called the *carapace.* Amongst these forms are a number of genera which have the last five pairs of legs of the thorax enlarged, to form the "ambulatory" appendages or "walking legs," for they alone are used in locomotion on the ground. Because of this characteristic they are known as the *Decapod* (ten-legged) *Crustacea*; here belong all prawns, crayfish, lobsters, and crabs, the first three being examples of the *Long-tailed Decapods*, and the last of the *Short-tailed Decapods.*

All Decapods have compound eyes borne on short movable stalks, of the same type as that illustrated on page 231.

Order I.: Decapoda

Long-tailed Decapod Crustacea

Type: **The Common Prawn** (*Palaemon serratus*).

The Common Edible Prawns live in shoals in rather deep water off our rocky sea-coasts, sometimes approaching the shore in large numbers. They are more common on the south and west coasts than on the east.

When alive their colour is a pale greenish-grey, very transparent and beautifully marked with red and brown. When boiled they turn a bright red, thus differing from shrimps, which become merely a pinkish-brown under the

same treatment. A full-grown prawn is about 4 inches long from head to tail, and the body is laterally compressed. Its general shape is shown in Fig. 112.

The Exo-skeleton. The exo-skeleton consists of the carapace, which covers the head and thorax dorsally and laterally; behind this, six separate shelly segments covering the back and sides of the first six abdominal segments; and finally a pointed tail-piece or *telson*. The carapace is extended forward as a strong-toothed beak or *rostrum.*

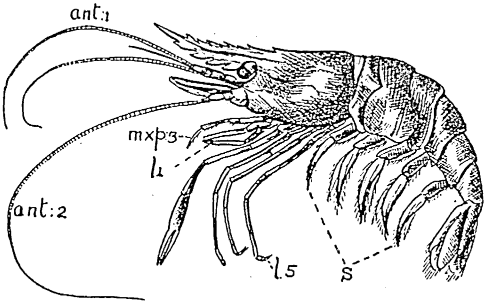

FIG. 112.—The Common Prawn (appendages of one side only shown).
ant_1, First antenna with two "flagellae"; ant_2, second antenna; mxp_3, third "jaw foot"; l_1 to l_5, five "walking legs"; s, swimmerets.

Ventrally, a thickened band or bar of the "shell" runs across each segment; these bars are distinct in the abdomen, but are much fused in the thoracic region, though still distinguishable. The carapace is thought to correspond to thirteen segments, and thirteen pairs of appendages spring from below it.

Appendages or Limbs. Attached to the soft cuticle between the ventral and lateral portions of the exo-skeleton are the limbs or appendages, one pair to each segment; these are much modified in different regions of the body to suit the function they have to perform (Fig. 113).

The head region of the carapace is separated from the thoracic region by a transverse groove on the back; it bears, besides the stalked eyes, two pairs of long feelers or antennae. Surrounding the mouth, which lies right below the head, are also the modified appendages known as the "mouth-parts." These consist here of one pair of hard biting jaws or *mandibles*,

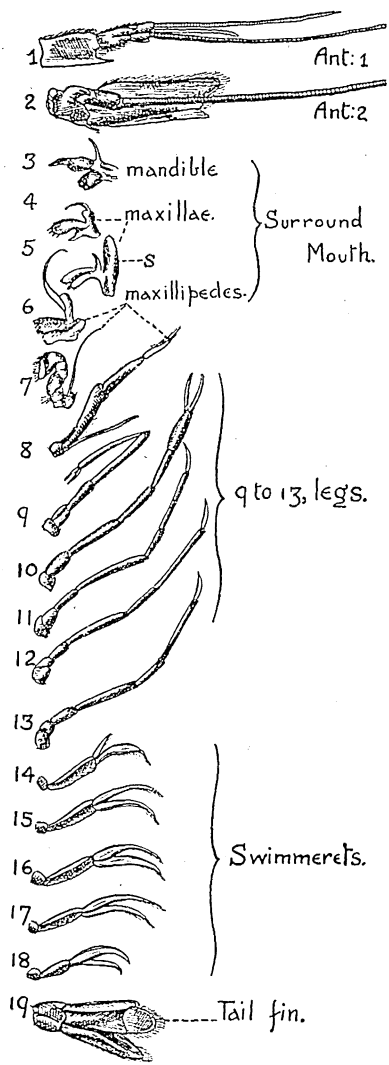

FIG. 113.—The Appendages of the Prawn removed from one side of the body and arranged in order.

s, Scaphognathite.

and two pairs of leaf-like "soft jaws" or *maxillae*, which perhaps help in the subdivision of the food before it enters the mouth. These first five pairs of appendages belong to the five segments of which the head is thought to be formed.

The first three pairs of *thoracic legs* are turned forward, and they also lie on the lateral borders of the mouth; they aid in passing the food into the mouth, and are therefore termed "jaw feet" (*maxillipedes*). The first two pairs of these jaw feet are much modified, and their basal joints aid in the division of the food, but the last pair far more closely resembles the remaining legs of the thorax.

The other thoracic legs, belonging to segments 9 to 13, are the most conspicuous of all, and are known as the "walking legs." In most Decapods they are all long and strong and seven-jointed, and the first two legs end in a little pincer-like claw; in the prawn, however, the first pair of "walking legs" is relatively

thin and delicate, and is turned forward on the top of the "jaw feet," lying doubled over just behind them, whilst the second pair is the largest of all, and bears the efficient pincers (*chelae*), with which the creature catches its prey. This is so in the Common Shrimp (*Crangon vulgaris*) also, but in the lobsters, crayfish, and crabs it is the *first* walking-legs that are specially enlarged, and bear the large pinching claws.

The *abdominal appendages* are modified for swimming. They are relatively short, and each is two-branched, the branches being fringed with hairs; the first five pairs, which are all much alike, are known as the *swimmerets*, whilst the sixth, the last pair, is broadened and flattened, and turns back to lie on either side of the tail segment, thus forming the tail "fin."

Movements. On the sea-bottom the prawn moves along on its "walking legs," but when swimming these appendages are used little, if at all. A gentle forward-swimming motion can be attained by the movements of the swimmerets, but when startled the prawn will dart suddenly backwards through the water. This it does by violently and suddenly lashing its whole tail forward under its body; this drives the water in front of it, and the reaction causes the body to jerk backwards.

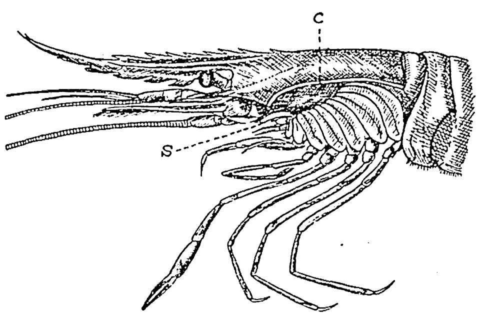

FIG. 114.—View of a Prawn, with one side of the Carapace cut away.

c, Cut edge of carapace; *s*, scaphognathite or plate of the 2nd maxilla.

Respiration. The gills or respiratory organs are hidden away in a cavity lying below the side "flaps" of the carapace, which should be cut away on one side, so as to expose the gills (Fig. 114). There will then be seen seven little white elongated plates, decreasing rapidly in size from the largest—attached to the body-wall just above the last walking leg—to the very minute little anterior one, attached

at the base of the second "jaw foot." These white plates are the gills in which the blood circulates, and in order to keep the blood aerated it is necessary that a constant current of water should pass over them. That this occurs can be demonstrated by putting a little carmine, or other easily visible but harmless powder, into sea-water with a living prawn, when the current will carry it in at the back margin of the side of the carapace, and out at the front margin. This current is maintained to some degree by the backward movement of the creature through the water, or, when it is at rest, by the movement of a little flat horny plate or "scaphognathite" attached to the second soft jaw or maxilla (Figs. 113 and 114, *s*); this plate, by its movement, jerks the water out of the gill chamber at its front margin, and so causes fresh water to enter from behind. The blood is almost colourless.

Reproduction. The sexes are distinct: the fertilised eggs are laid and are carried by the female attached to some of her swimmerets until they hatch; they are then protected in a brood-pouch made by the bending forward of the abdomen.

The *larval prawns* which hatch out are very unlike the adult: they are little, soft, transparent creatures with only rudiments of the thoracic walking legs, although all the appendages in front of these are well developed; the abdomen also, though fully segmented, has at first no appendages; those on the sixth segment appear first, but the others do not develop until all the thoracic legs are complete. These larvae are known as *Zooea* larvae. (Cp. Zooea of Crab, Fig. 117.)

Moulting or Ecdysis. As the immature larva develops, it goes through a series of moults, and when it has acquired its final form and hard exo-skeleton the moult is still continued periodically, to allow for the further growth of the body.

When the prawn is about to moult, its shell splits across the back, just between the thorax and abdomen, and the prawn gradually withdraws from the old shell first its head, thorax, and anterior limbs, and then its abdomen. The body is covered by the new exo-skeleton which has been formed beneath the old, but this is still quite soft, and whilst in this defenceless condition the animal has to remain

hidden in some sheltered corner for fear of enemies; gradually the exo-skeleton hardens and active life is resumed.

At every moult, not only the external shell is shed, but also the lining of the gullet and gizzard (the first part of the stomach). This *gizzard* has on its inner walls thickenings of the cuticle forming hard ridges, and also projecting teeth. By means of special muscles these can be made to grind one on another, and so the food swallowed is thoroughly masticated.

Senses. The compound, stalked eyes must give a wide range of vision and the *sight* seems fairly keen; the sense of *touch* is specially located in the delicate antennae. In the basal joint of each of the first antennae there is a little cavity, from the walls of which spring hairs supplied with nerves at their bases; the cavity contains a slightly gelatinous liquid in which are small solid particles, placed there apparently by the prawn itself. This little organ, which is in free communication through a small opening with the water outside, is undoubtedly an *organ of equilibrium*, and probably an *auditory organ* as well. The prawn is thought to have likewise a sense of *smell* located in certain peculiar hairs on both pairs of antennae.

Other Long-tailed Decapod Crustacea.

The Common Shrimp. The Shrimp (*Crangon vulgaris*) is very common on our shores, and can be at once distinguished from the common prawn by its smaller size, by the form of its body, which is flattened from above rather than laterally, and by the absence of a prolonged rostrum, as also by the already mentioned fact that it does not turn a bright red when boiled.

Lobsters and Crayfishes. Lobsters and Crayfishes have very similar structure to that of shrimps and prawns, though they are, of course, much larger.

In lobsters the first "walking legs," which are the largest, are nearly always unequal in size on the two sides, one forming smaller cutting nippers, whilst the other is larger for crushing food. These legs have apparently six instead of the usual seven joints, for the second and third joints are fused together. A curious characteristic of these, and of many Crustacea, is their power of casting off part of a limb if

it is injured or seized by an enemy; the end of the leg is voluntarily cast away, the breaking point being always across the centre of the second and third fused joints; excessive bleeding at this point is prevented by a special membrane, which is pushed inwards at the point of rupture. Within the membrane a new miniature limb is formed which, when next the shell is cast off, elongates rapidly and becomes functional.

All young lobsters and the adult males are said to moult twice a year, but adult females only once; it is a dangerous process, and not infrequently causes the death of the creature, either owing to some injury received whilst moulting is taking place, or to its defenceless condition if some enemy should then find it.

Lobsters breed only once in two years, usually in July or August, when each female will produce as many as 160,000 eggs! These are carried by the female on her swimmerets for ten or eleven months, and during this time the trapping of such lobsters (said technically to be "in berry") is forbidden by law.

Short-tailed Decapod Crustacea

Crabs. Crabs are essentially similar in general structure to lobsters and shrimps, the great difference in their appearance being due to the fact that the abdomen is permanently bent right under the thorax, so that it can only be seen from below (Fig. 115). Moreover, the carapace is very thick and strong, and is widened laterally, so that in most forms its width is greater than its length. The antennae which project forward are relatively small, and the mouth-parts are covered by the broad, flat, third "jaw feet" (*maxillipedes*); the "walking legs" are very strong, and the first pair bear very large, powerful chelae or pincers. In the Edible Crab (*Cancer*) and in the Common Shore Crab (*Carcinus*) the large legs are adapted only for walking, and the crabs move by scuttling sideways at a good pace over the ground. In the Swimming Crab or Fiddler (*Portunus*), shown in Fig. 115, the last pair of legs is flattened and fringed with hairs, so that they form swimming paddles, by the movement of which the crab darts through the water.

The abdominal appendages or swimmerets, having lost their primary function of aiding in locomotion, are much

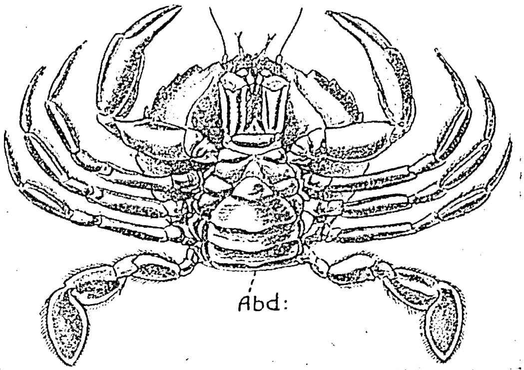

FIG. 115.—A Swimming Crab (*Portunus*).
(Seen from below.)

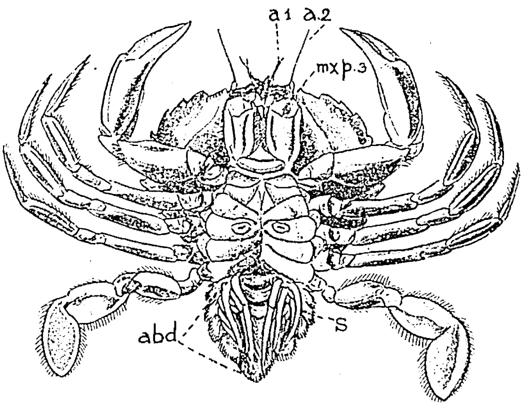

FIG. 116.—*Portunus*, from below, with the abdomen pulled down to expose *s*, the swimmerets ; a_1, a_2, the antennae ; mxp_3, the 3rd "jaw foot."

reduced. However, it is possible to see them if the abdomen is gently pulled down into the position shown in Fig. 116.

In the common Spider Crab the front of the carapace, or

"forehead," is not rounded as in the Shore Crab and Swimming Crab, but is prolonged in front into a sharply pointed rostrum. The popular name of these creatures is due to the great length of their "walking legs" in comparison to the size of their body.

Development of Crabs. The development of crabs is specially interesting. From the eggs hatch out small, transparent, free-swimming larvae (Fig. 117), each with a carapace armed with two long spines; a pair of large dark eyes is also present. The rudiments of the antennae and the

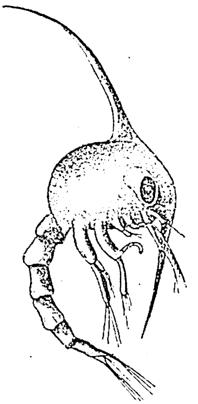

FIG. 117.—*Zooea* Larva of Crab. × 20.

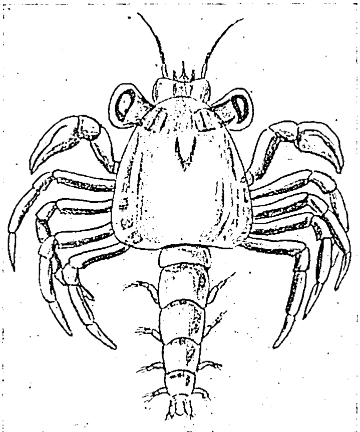

FIG. 118.—*Megalopa* Larva of a Crab. × 20.

first two pairs of jaw feet are developed, but no appendages further back than these. The long abdomen ends in a forked tail. This larva is known as a *zooea* larva (Fig. 117).

Gradually the other thoracic appendages develop and also the swimmerets on the abdomen; the skin moults at intervals, and finally the larva sinks to the ground, looking rather like a little crayfish its "walking" legs having by now developed (Fig. 118); this is known as the *Megalopa* stage. When once it has taken to ground life, and has ceased to use its abdomen in swimming, the larva changes rapidly to the adult crab form; the carapace broadens and the unused abdomen is tucked away. Having acquired the adult form, the

little crab moults its shell regularly, and it is interesting to collect the whole series of shells obtained from a single shore crab.

Such a series is shown in Fig. 119, which is a photograph of specimens obtained from a single crab between May 1901 and July 1904, and exhibited in the British Museum.

Hermit Crabs. The Hermit Crab (*Pagurus*) is peculiar because of its custom of inhabiting some empty Gastropod shell, usually that of a whelk (Fig. 120).

The hermit protrudes its head and great legs from the shell, but tucks its soft, long abdomen away inside, twisting it right round into the spiral cavity of the whelk shell. The soft abdomen protected in this way is very unlike that of other Crustacea, for not only has the hard exo-skeleton disappeared, but it is also asymmetrical (Fig. 121). Many of the abdominal appendages have disappeared, and those that remain are unequally developed on the two sides; the last swimmeret of the left side forms a kind of hook, with which the crab holds on to the central column of the shell; the last swimmeret on the right side is smaller, but used for the same purpose. All the other appendages of the right side of

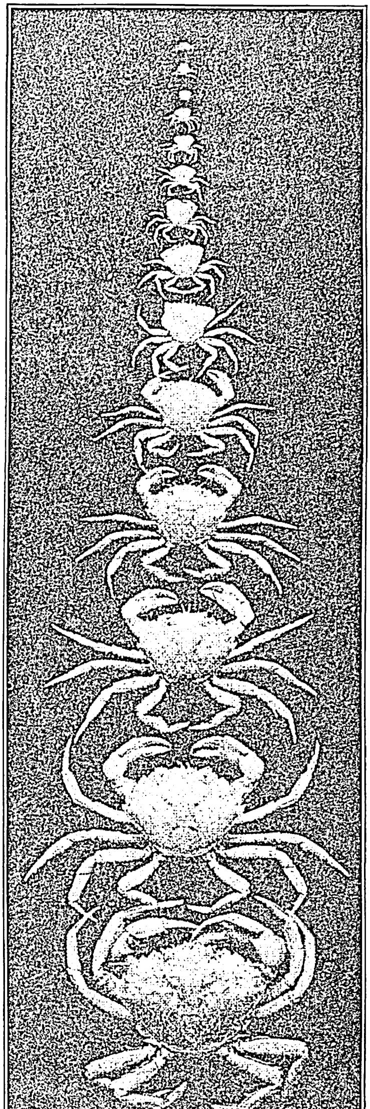

FIG. 119.—Series of cast shells obtained from a single individual Shore Crab (*Carcinus maenas*) kept in an aquarium. The largest of these shells was 2½ in. wide.

the abdomen are absent or very rudimentary, but the first three on the left side of the body in the female are fairly large and hairy, being used by her for carrying the eggs; a fourth rudimentary swimmeret may be present further down the abdomen. In the male, these appendages are all very small. It will be seen also that in both sexes the fourth and fifth "walking legs" are small and do not project from the shell.

These hermit crabs can withdraw almost entirely into the

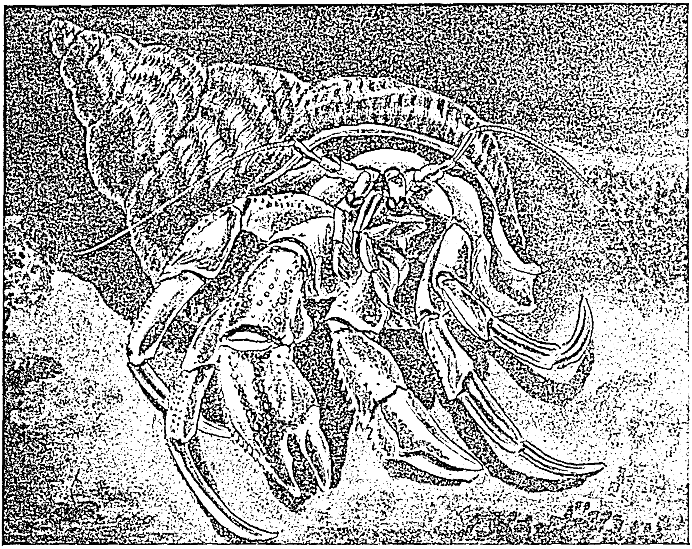

FIG. 120.—A Hermit Crab (*Pagurus*) inhabiting a whelk shell.

shell, shutting themselves in by holding the much enlarged right claw over the shell entrance.

Although so curiously asymmetrical when adult, these hermit crabs begin life as little symmetrical *zooea* larvae, very similar to those of ordinary crabs, though without the long spines; they remain symmetrical up to a stage corresponding to the *megalopa* larva of crabs, when they have five pairs of equally developed swimmerets; they then give up an active life and settle at the sea bottom, and the right side of the body begins to degenerate and its internal organs to shift in position. Now the larva finds a small shell to fit

it, and takes up its abode in it. As it grows too big for one shell it searches for another, bigger, empty shell, or it may actually turn out the rightful owner and forcibly take possession of its shell.

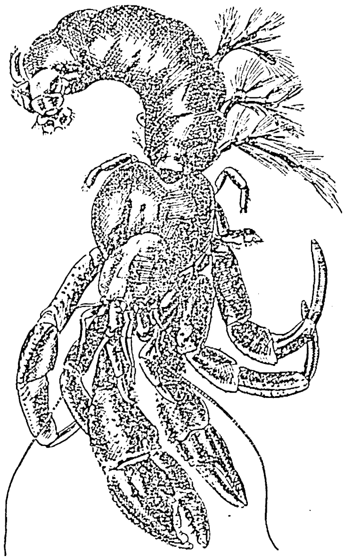

FIG. 121.—A female Hermit Crab removed from a whelk shell to show the soft asymmetrical Abdomen.

A curious, well-known fact about the hermit crabs is their custom of living in partnership with certain other creatures; *e.g.* a beautiful sea Bristle-worm (*Nereis fucata*) is very frequently to be found *within* the shell, whilst attached externally there may be one or more special sea anemones or a cluster of the little zoophyte *Hydractinia*, or a bright orange sponge that grows over and into the shell, closely investing it and rendering it unpalatable to many of the enemies of the hermit crab, for the sponge tissues are full of little flint needles.[1] Though the crab is carnivorous, all these associated forms live peaceably together, the guests feeding off the discarded morsels of the crab's meal.

SESSILE-EYED CRUSTACEA

Besides the Decapods already described, there are other Crustacea which have more definitely segmented bodies, and in which eight thoracic and usually six abdominal segments bearing appendages can be recognised, but in which the carapace is absent, or is represented merely by the chitinous skin of the head fused with one or a few thoracic segments. In these forms the limbs are never branched, and the eyes, though compound, are always sessile.

[1] See discussion in *The Wonder of Life*, by Prof. J. A. Thomson, on "Commensalism," or the external association of two creatures for their mutual advantage.

O

To this group belong the freshwater shrimps, the wood-lice, and the water slaters.

Order 2: AMPHIPODA[1]

Freshwater Shrimps. The Freshwater Shrimp (*Gammarus*) is a small form, very plentiful indeed in rivers and ponds, where it acts as a scavenger, feeding on any dead animal or vegetable matter.

The light brownish body is about $\frac{1}{2}$ an inch long and is laterally compressed. On the first division of the body can be seen two pairs of long antennae and the first thoracic appendages, the jaws being hidden; next come seven distinct thoracic segments, each bearing a pair of jointed legs with a plate-like gill attached to the base of each. The abdomen consists of six segments bearing smaller, hairy appendages, and, at the end of the body, a small single tail-piece or telson, as in shrimps and prawns.

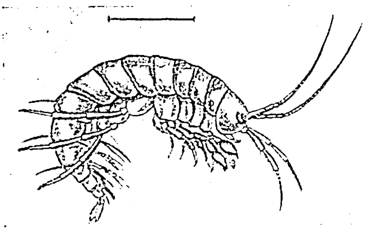

FIG. 122.—The Freshwater Shrimp (*Gammarus pulex*).
(Natural size shown by the line above.)

The name *Amphipoda*, given to this order of Crustacea, refers possibly to the two types of ambulatory limbs which are obvious on the thorax of *Gammarus*, and also possibly to the two kinds of abdominal limbs, the three anterior pairs being branched, swimming organs, whilst the three last pairs are peculiar stiff processes used in jumping.

Gammarus swims very actively, either by the movements of the abdomen, or by jerking itself along with the three last pairs of thoracic legs. The three anterior pairs of abdominal legs are always in motion, driving a current of water over the gills.

The male is considerably bigger than the female, and is often to be seen carrying the female in front of him, holding her by the anterior thoracic legs.

Sand-hoppers and Shore-hoppers are very similar to the

[1] See page 198 for classification and general characteristics.

freshwater shrimps, and also are invaluable scavengers; they are common everywhere on our coasts, burrowing in the sand above high-water mark.

Order 3: ISOPODA[1]

Water Slaters. The Common Water Slater, or Water Louse (*Asellus aquaticus*), is, like *Gammarus*, a small scavenger very common in pond and river (Fig. 123). It differs, however, in having its body flattened dorso-ventrally instead of laterally, and all its legs of the same general type (hence the name of the order, *Isopoda*). Also the gills are attached to the abdominal appendages instead of to those of the thorax, and the abdomen is much reduced in size.

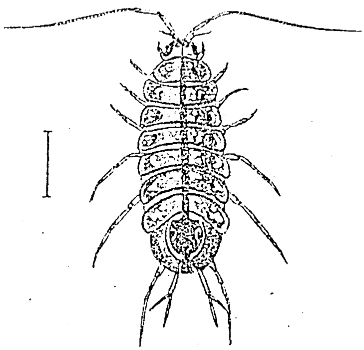

FIG. 123.—The Water Slater (*Asellus aquaticus*).
(Actual length is shown by the line to the left.)

Wood-lice. Wood-lice or Land Slaters are adapted to some extent to life on land, for the inner plates of their abdominal legs form "gills" containing little air-tubes somewhat like the tracheae of insects; the outer plates act as covers for these gills, so that they do not dry up, for although they can breathe air they are still dependent on moisture, and without it they speedily die; they are therefore usually found living beneath a stone or a log of wood, or in some other sheltered and damp spot.

They have a special way of protecting their young; a pair of plates grow inwards from the sides of the second to the fifth thoracic segments; these plates overlap below, but a space is left between them and the body so that a "brood-pouch" is formed, into which, at the beginning of the summer, the eggs

[1] See page 198 for general characteristics.

are deposited, and here the little ones are carried for some time. Wood-lice feed on mixed animal and vegetable diet, and since they are said to attack seedlings they are eyed with disfavour by the gardener.

J. B. Casserley has given an interesting description[1] of how the wood-louse sheds its skin. First it discards the back half, protecting the soft, new, exposed part by poking it into a corner. It then eats the discarded half skin and remains quiescent for three days, after which it throws off the front half of its old skin. The soft tissues now exposed in front tempt even its own kind to attack it, so that for safety's sake it must be isolated, if it is being kept in captivity, for three more days, when this front half also will have hardened. A specimen $\frac{1}{2}$ inch long will only moult once in six months.

The commonest and one of the largest of British Wood-lice is the Garden Slater (*Oniscus asellus*). It has a rather broad, slate-grey body with yellow markings, and the tail appendages project behind the body as the animal walks. It is $\frac{1}{2}$ inch to $\frac{7}{10}$ inch long.

The Common Wood-louse (*Armadillidium vulgare*) is easily recognised by its habit of rolling up into a ball like an Armadillo, when touched; also its tail appendages are not visible as it walks, and the antennae are tucked away when it rolls up.

The White Slater (*Platyarthrus Hoffmannseggii*) (Fig. 124) is a much smaller, but fairly common form, not more than $\frac{1}{10}$ of an inch long; it is notable because it always lives in the nests of ants, apparently welcomed and cared for by them (see p. 458). These white slaters are quite blind, and they have thick, rather short antennae.

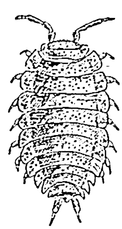

FIG. 124.—The White Slater (*Platyarthrus Hoffmannseggii*). (Actual length $\frac{1}{10}$th inch.)

LOWER CRUSTACEA (ENTOMOSTRACA)

All the Lower Crustacea are small, primitive forms in which the segmentation of the body and the form of the appendages are very variable. They often have a single median simple eye as well as two lateral compound eyes.

[1] Quoted by W. M. Webb in *The British Wood-lice*, Webb and Sillem.

Order 1: Branchiopoda

The Water Flea, Daphnia. The little Crustaceans known as Water Fleas are very minute, and extremely transparent, but in spite of this they can be readily seen in the water of a clear pond, as they swim up and down with a curious jerky movement in the early morning and the evening; during the hotter hours of the day they rest on the mud bottom. The name of the order refers to the leaf-like swimming appendages (Fig. 125).

The commonest species is *Daphnia pulex.* The carapace is compressed laterally, so that it forms a covering like a bivalve shell; it has a spine projecting backwards from its hinder end, and the head projecting in front. On the head are the two large compound eyes which have fused together to form a beautiful conspicuous structure. The first antennae are rudimentary, but the second are very large and branched, for they form the organs of locomotion. The jaws (mandibles and first maxillae) are not visible in Fig. 125, but below the head can be seen the five thoracic limbs of one side.

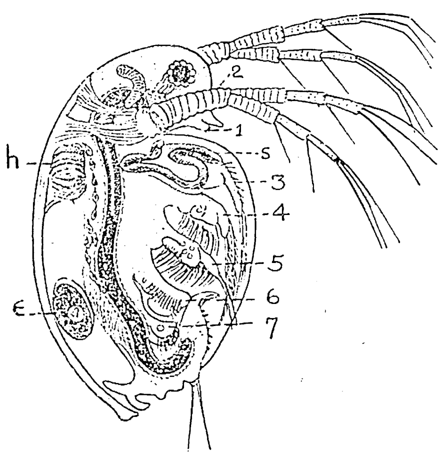

Fig. 125.—*Simocephalus*, one of the Water Fleas. ×20.

(Very like *Daphnia* but without the dorsal spine at the end of the carapace.)

s, Shell-gland; *h*, heart; *e*, egg; 1, 1st antenna; 2, 2nd antenna; 3-7, thoracic limbs.

The abdomen has no appendages, and terminates on each side of the anus in a plate bearing a curved spine. The alimentary canal is clearly visible through the transparent body, and also, lying dorsally, the heart can be seen, and in the female the "brood-pouch" in which the eggs are laid. During the summer the eggs laid are not fertilised, and yet

develop into new individuals, an example of the phenomenon known as *parthenogenesis.* The new individuals produced may again give rise only to other parthenogenetic females and so on for several generations, but finally there appear males as well—this is always so in late autumn. The eggs then produced are fertilised and form the "winter eggs" round which the cuticle of the carapace hardens, forming an egg-case which is shed into the water, and within which the eggs remain dormant until the following spring; they then give rise to females only, which reproduce parthenogenetically.

Order 2: COPEPODA

Cyclops. *Cyclops* is another minute Crustacean very common in stagnant water; The first antennae are in this case the largest of all the appendages and they help in locomotion; there is a single simple median eye. The female carries two egg-sacs, attached one on each side of the abdomen (Fig. 126). In these the eggs are carried until they hatch. *Cyclops* multiplies with astonishing rapidity. Together with *Daphnia*, it forms the staple food of many other water-inhabiting creatures.

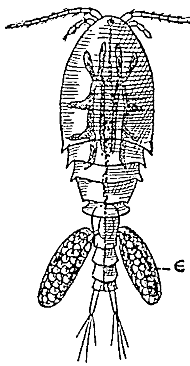

FIG. 126.—*Cyclops.* ×20. *e*, Egg-bag.

Order 3: OSTRACODA

Cypris. *Cypris* again is a minute, single-eyed form to be found in ponds. The body is transparent and is enclosed in a bivalve carapace, owing to which *Cypris* was at one time confused with the bivalve molluscs. Its jointed appendages, however, indicate its true affinity.

With the aid of a lens two pairs of unbranched, jointed antennae may be distinguished, and—near the hind end of the body—two pairs of short, jointed legs which may project beyond the shell. The second pair, however, is usually turned backwards and upwards, so that it is covered by the shell though it may be visible through it (Fig. 127).

Sometimes the mouth appendages, too, may be seen, though the shell must be removed for all to be visible.

There is one pair of mandibles and two pairs of maxillae, of which the first pair is the larger and bears a branchial plate fringed with hairs. The second pair is small and difficult to detect.

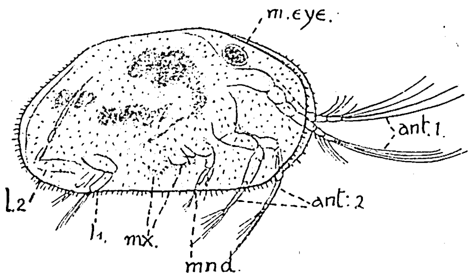

FIG. 127.—*Cypris*. ×25.

m. eye, Median eye ; ant_1, ant_2, 1st and 2nd antennae ; *mnd*, mandibles ; *mx*, maxillae ; l_1, l_2, legs.

The body ends in two long processes, which are said to be used in cleaning the shell. They often project from the body when the *Cypris* is swimming.

There is another little form, *Candona*, which is very similar to *Cypris* in structure, but which lives a far less active life, usually creeping over the mud at the bottom of a pond. It can be distinguished from *Cypris* by its narrower shell and by the absence of the conspicuous tuft of hairs on the second antennae, which characterises the latter.

In both these genera, parthenogenetic reproduction seems the rule. In many species, males have never yet been discovered.

Order 4: Cirripedia

Barnacles or Curl-footed Crustaceans

Acorn Barnacles. The common Acorn Barnacles (*Balanus tintinnabulum*) are probably well known to all, for to them belong the hard, sharp-pointed, conical shells that are so plentiful on our shores on rocks and timber near high tide mark. This species may be an inch high. A much smaller species of *Balanus* often completely covers the rocks.

When exposed at low tide, these shells can easily be obtained by chipping off a piece of the rock on which they grow; if then transferred to a bowl of sea-water their structure can be investigated.

The *shell* is calcareous, and is composed of a hard base fixing it to the rock, from which stands up a ring of six more or less triangular pieces; these are fused together laterally, and the top is protected by four smaller movable plates. Inside this case the animal can lie entirely hidden and well protected; when submerged in the water, and desiring food, it lifts the four upper valves so that an opening is disclosed centrally, and through this there slowly appear a number of beautiful little curved feathery appendages, which by their lashing movement catch any food particles in the water, driving them down in a current of water into the mouth, which lies hidden within, and which has mandibles and two pairs of soft jaws (*maxillae*) with which to masticate the food.

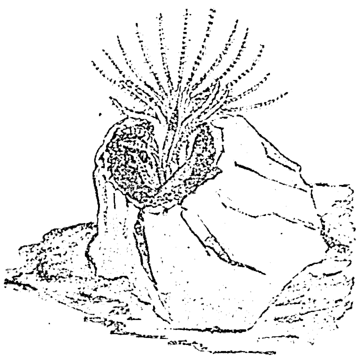

FIG. 128.—The Shore Barnacle attached to a rock (external momentary view when feeding).

If the animal is startled, the projecting appendages are very rapidly withdrawn, and the shell tightly closed once more.

To investigate the structure more thoroughly, it is necessary to break away one side of the hard case of a dead specimen, and expose the body and limbs as shown in Fig. 129. Even then the structure is difficult to understand, and can only be rightly

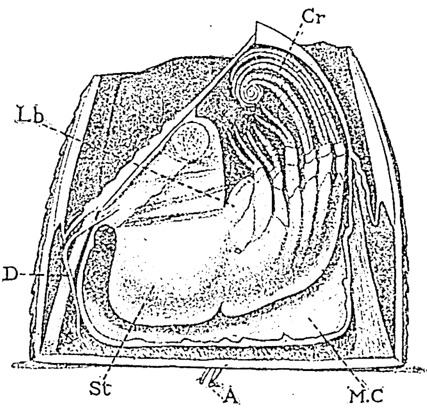

FIG. 129.—The Acorn Barnacle with the right half of the shell removed. (After Darwin.)

A, Antennae; *St*, stomach; *Lb*, upper lip, covering mouth; *Cr*, thoracic legs; *MC*, mantle cavity; *D*, oviduct.

interpreted in the light of a knowledge of its mode of development from the little free-swimming, one-eyed, six-legged larva that hatches from the egg and gradually changes to the adult form. This larva becomes Cypris-like with a bivalve shell, and then after a time fixes itself, back downwards, to some object by means of its tiny first antennae (Fig. 129, *A*). The head much enlarges and alters; the creature loses its bivalve shell and secretes the base of another, fixing it to a rock; then the mantle of skin round the body secretes the rest of the shell-plates. Finally there results a curiously modified, degenerate creature such as is shown in the figure, which lies on its back with its head attached to its shell, and with its mouth placed half-way down the body-mass (Fig. 129), close to the bases of six pairs of two-branched thoracic legs, which project beyond the shell when it is open and drive the food into the mouth. The abdomen is reduced to a little stump.

Most barnacles are hermaphrodite, and the long tube (penis) from the spermary may sometimes be seen projecting from the shell beyond the thoracic limbs. The sense organs are all degenerate, except for the tactile hairs present on the limbs.

The barnacle is a curious case of retrograde development and an example of modification of structure resulting from a change of habit.

The Stalked Barnacles, or Goose Barnacles (*Lepas anatifera*), are very similar in structure to the Acorn Barnacles except for the presence of the long fleshy stalk formed from the region of the head below the first antennae, this region having become much swollen and elongated.

Before dry docks became customary, these barnacles often used to become so numerous on the bottom of a ship that they had to be scraped off by divers when the ship was in harbour.

The name "Goose Barnacle" refers to the old legend, apparently of Scotch or Irish origin, that from each barnacle shell there hatched out a complete little bird like a miniature goose. This legend was believed even in the seventeenth century, when it was inscribed in the *Transactions of the Royal Society*!

General Classification of the Crustacea mentioned in Chapter XII.

I. **Higher Crustacea (Malacostraca).**—Those with a definite number of segments and appendages.

Order 1. *Decapoda.*—Those with five pairs of walking legs and with compound, stalked eyes; the carapace includes head and all thoracic segments.

(*a*) Long-tailed forms: Prawn, Lobster, etc.

(*b*) Short-tailed forms: Crabs.

(*c*) Soft-tailed forms: Hermit Crabs.

Order 2. *Amphipoda.*—In this order the carapace includes only one, or a few, of the thoracic segments, leaving others free; the body is laterally compressed; the gills are attached to the thoracic legs, which differ also in form from the abdominal legs; the eyes are sessile: *e.g. Gammarus*, the Fresh-water Shrimp.

Order 3. *Isopoda.*—In the Isopoda the head fuses with only one thoracic segment, the body is flattened dorso-ventrally, the legs are all of the same type, the gills are attached to the abdominal segments, the eyes are sessile: *e.g. Asellus*, the Water Slater; *Oniscus*, the Garden Slater; *Armadillidium*, the Wood-louse; *Platyarthrus*, the White Slater.

II **Lower Crustacea (Entomostraca).**—These are small forms with variable segmentation; a median simple eye may be present as well as compound eyes.

Order 1. *Branchiopoda.*—Small forms with leaf-like swimming appendages, usually with simple and compound eyes; a large carapace is often present, *e.g.* in *Daphnia*, the Water Flea.

Order 2. *Copepoda.*—Small forms with no carapace and usually about sixteen segments altogether; compound eyes absent: *e.g. Cyclops.*

Order 3. *Ostracoda.*—Small forms usually of about eight segments only, enclosed within a carapace having a bivalve form: *e.g. Cypris, Candona.*

Order 4. *Cirripedia.*—Much modified, sedentary Crustacea, with a body of a few segments surrounded by a fold of skin, which secretes in most cases a number of calcified plates that form a hard case round the body: *e.g. Balanus*, the Acorn Barnacle; *Lepas*, the Goose Barnacle.

Practical Work on Crustacea

1. *Study of Living Crustacea.*—A live common *shrimp*, or better still a small *prawn*, may be got straight from the sea or from some marine biological station, and its habits watched in the sea-water tank. When these Crustacea are kept in the tank, the bottom of it should always be covered, at any rate partly, with sea sand, to the depth of an inch or two, since the shrimp likes to bury itself in this; the water must be well aerated. Large anemones must not inhabit the same tank, for they will devour their fellow-lodgers. The Crustaceans can be fed on little morsels of fish. They are often useful in a tank, for they will eat up any small particles of food dropped by the other inhabitants.

A very small crab and a small hermit crab may be kept under the same conditions as the prawn, but care must be taken not to overcrowd the tank, as these creatures will only thrive when there is plenty of oxygen in the water. When a hermit crab is kept, it must be given a selection of shells larger than the one it is inhabiting, so that it may "move" when its increase in size makes this desirable.

2. *Investigation of the Structure of Crustacea.*—Dead shrimps or prawns and a small crab can easily be obtained from the fishmonger, and their structure investigated; sketches should be made in illustration.

3. *Study of the smaller living Crustacea.*—Fresh-water shrimps, Water Slaters, Water Fleas, Cyclops, and Cypris may usually be easily obtained by drawing a fine net through the water of any pond which has plenty of vegetation in it. Interesting experiments may be carried out to illustrate the rapidity with which some of these forms multiply. Single specimens of the water flea (*Daphnia*) should be isolated, and the curious parthenogenesis which occurs noted.

When possible all the more minute of these creatures should be examined under the microscope, when their beauty and complexity of structure will become more apparent. Enlarged sketches should be made of them.

4. *Wood-lice* should be hunted for under stones or logs of wood. They may be identified by reference to *British Woodlice*, by Webb and Sillem. There are twenty-five different British species.

Their curious ways may be watched if they are kept in a "live-box," a tin with a glass lid and small air holes round its sides, and with a floor $\frac{1}{4}$ inch thick of plaster of Paris which can be soaked with water so that the air above is kept permanently damp.

CHAPTER XIV

ARTHROPODA (*continued*)

Class II.: ARACHNIDA

(Spiders, Harvestmen, and Mites)

General Characteristics. The class Arachnida is a very large one, including many diverse orders, of which only three will be mentioned here, viz. the *Araneae* or true Spiders, the *Phalangidea* or Harvestmen, and the *Acari* or Mites.

All the Arachnida are alike in being air-breathing forms, and in having the head and thorax fused together to form the "cephalo-thorax." The head bears no true antennae, and only two pairs of jaws. There are four pairs of walking legs. The abdomen is segmented in some and not in others; in the Mites it is not differentiated from the thorax. The sense organs are simpler than in other Arthropods, the eyes being simple and sessile; there is as a rule no metamorphosis in the development, the young being like the adult except for size.

Order I.: Araneae (The True Spiders)

Spiders are Arachnids in which the abdomen is unsegmented, and separated from the cephalo-thorax by a narrow constriction or "waist." On the under side of the abdomen, rather near its apex, are special spinning organs or *spinnerets*, from which are produced the silk threads with which a spider spins her characteristic snare or web. The head bears no antennae. It has usually eight simple eyes, but the number varies in different species; the mouth is flanked by two pairs of appendages—a pair of two-jointed jaws, *chelicerae* (often

spoken of as the mandibles, though probably not homologous with the mandibles of insects), and a pair of six-jointed feelers, very like legs, known here as the *pedipalps.* The last joint of the latter contains, in the adult male spider, a complex "palpal organ"—a sexual organ in which the sperm cells are temporarily stored (Fig. 131, *pp*). The structure and life-history of the Common Garden Spider will elucidate many points in the structure and life-history of the Araneae generally.

Type: The Common Cross Spider (*Epeira diademata*).

Epeira diademata is the largest of our common garden spiders, and in the autumn, when it is full grown, it is easily found in nearly every garden, where its large, vertical, beautifully constructed web will be hung in many a sheltered corner.

General Form. The spider is a brownish-yellow or reddish-brown colour of varying shades, and it can readily be recognised, when viewed from above (Fig. 130), by the white spots and lines on the back of the abdomen, arranged in the form of a cross, whence the creature gets its name of "cross" spider. The body of the female spider may be quite $\frac{3}{5}$ths of an inch long, but the male is a little smaller. In a dorsal view, the union of head and thorax is obvious, but the constriction between thorax and abdomen is largely hidden by the overhanging of the latter.

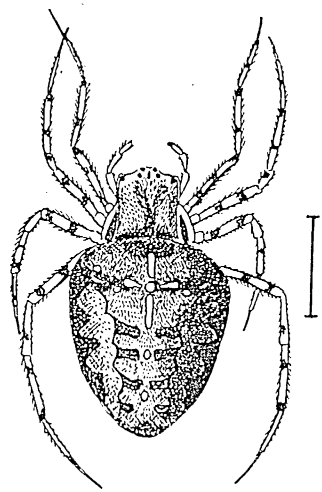

FIG. 130.—The Common Cross Spider (*Epeira diademata*). (View from above. The line to the right shows the actual length.)

The Head. On the head of the spider shown can be seen the eight simple eyes and the forwardly projecting pedipalps, but the jaws, which hang down vertically, are not visible. These are best examined from a front view such as

that given of the House Spider in Fig. 131, in which the two joints of the jaws can be seen; the sharply pointed end joint is able to close at will on the basal joint, like the blade of a clasp-knife. The jaws are moved sideways in *Epeira* and in all British spiders, with the single exception of one little burrowing form (*Atypus*), in which they work with an up-and-down motion.

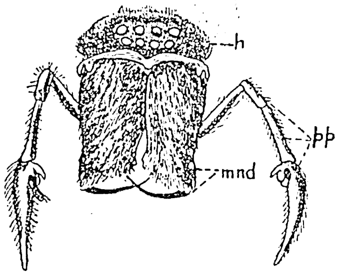

FIG. 131.—The House Spider (*Tegenaria domestica*).
View of the head seen from the front.
h, Head; *pp*, pedipalp; *mnd*, jaw or chelicera.

If the basal joint of one of these jaws or fangs is dissected, inside there will be found a *poison gland*, from which, when the spider seizes his prey, poison runs down through a narrow duct and out of an opening near the tip of the sharply pointed terminal joint, finally entering the wound made by the bite and paralysing or killing the victim.

The *pedipalps* consist mainly of the four terminal soft joints which act as feelers, but the basal joint next the mouth is hard, and functions as an extra jaw in masticating the food. The *mouth*, which lies below the jaws, is difficult to find, for it is hidden between two fleshy processes which adhere to one another when the mouth is not in use.

The Thorax. The under part of the thorax bears four pairs of seven-jointed, hairy legs, coloured characteristically in *Epeira* with dark bands running across the general, lighter surface. Each leg bears on its end joint a pair of toothed claws, below them a hooked median claw, and below this again some stiff serrate hairs. By means of these the spider can run along or up the thinnest silk thread with perfect security. On the last two legs, the claws can be moved to grasp things, and when

FIG. 132.—Tarsus or Foot of *Epeira diademata*.

hanging from a thread, it is always with these opposable claws that the spider grips.

The Abdomen and its Spinnerets.

The much swollen abdomen bears underneath, near its tip, the spinning glands or "spinnerets." These consist of three pairs of short, very mobile processes. The second pair in *Epeira* is hidden below the others when not in use, consequently only two pairs show in Fig. 133; these two are each two-jointed, but the median inner pair has only one joint.

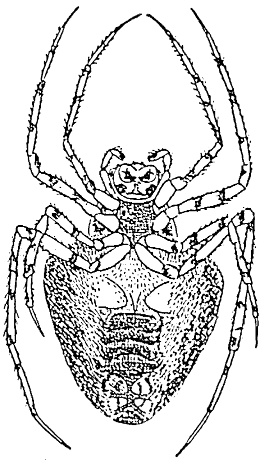

FIG. 133.—*Epeira diademata.* Ventral view showing jaws, pedipalps, legs, two pairs of spinnerets, and anal papilla.

At the tip of each process are small projections of different sizes, on which are the openings of the silk-spinning glands of the abdomen. As many as 600 glands open on separate little projections on the three pairs of spinnerets; from each of these a gummy fluid can be emitted which, as it dries in the air, forms a fine silken thread. Certain of the projections are larger than the others, and are known as the "spigots," to distinguish them from the much smaller and more numerous processes, known as the "spools." There is one spigot on each of the first pair of spinnerets, three on each of the second, and five on each of the third pair. The spigots and spools have their own special functions, the former giving out stronger, coarser silk threads than the latter; the silk used in making the lines of the web is usually emitted from the spigots of the first pair of spinnerets alone, though sometimes a spigot on each of the median spinnerets adds an additional strengthening strand; the web threads are therefore double or sometimes fourfold, the strands adhering to each other along their whole length, but being quite easily separable. The popular idea that these threads consist of many strands woven into one by the spider is erroneous; it arose probably from the fact that each of the main threads is tethered, as it were, to its point of attachment by a number

of extra, very small, fine threads which are given out by the spools for this purpose, but which are quite distinct from the "spigot threads" which form the line.

Other details of the uses of special spigots or spools are given below in describing the web-formation.[1] The action of the spinnerets can be readily seen when the spider is making her web.

Just below the spinnerets is the *anus*, situated on a little process which projects forwards (Fig. 134).

The spinnerets are clearly shown in Fig. 134, which, however, is taken from the spider *Amaurobius*, a genus fairly common in cellars and under stones and bark. It differs from the garden spider in the position of the median spinnerets (they are hidden in *Epeira*), and in the presence of the *cribellum*, a special sieve-like area covering extra silk glands. The silk from these is drawn out of the pores by the stroking action of a row of stiff bristles, like hairs, on the fourth pair of legs.

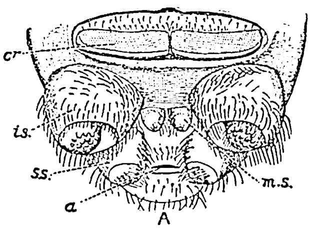

FIG. 134.—Spinnerets of the Spider *Amaurobius*.
a, Anus; *cr*, cribellum; *is*, *ms*, *ss*, spinnerets.

There is no segmentation of the abdomen to be seen, though a few bands of darker coloration occur just above the spinnerets. These have, however, nothing to do with any true segmentation.

Lung-books and Tracheae. In front of the darker patch on the abdomen can be seen the two transverse slits, which lead into the respiratory organs, known as the "lung-books." (These slit-like spiracles, or "stigmata," are shown in Fig. 133 as the lower line on each of the two light areas below the abdomen.)

The special kind of respiratory organs known as "lung-books" occurs only in air-breathing Arachnids.

Each of the stigmata opens into a small cavity extending forward. From the front wall of this cavity there project into it a number of thin plates, usually 15 to 20 of them; these are the "leaves" of the lung-book. Each leaf, however, is

[1] See also paper by C. Warburton in the *Q. J. Micr. Sci.* for April 1890.

hollow and contains blood, and this is purified by the air taken into the cavity through the stigma. The purified blood is carried back to the heart by a special blood-vessel.

Besides these lung-books, there are within the body "tracheae" or air-tubes such as those found in insects (see p. 234). These open by a single median aperture (spiracle) behind the lung-books. (In Fig. 133 this aperture is concealed in the darkly coloured patch.)

Between the stigmata of the lung-books is seen a little backwardly projecting process which contains the ovipositor or egg-laying apparatus of the female. This process (*epigyne*) is only present in the full-grown spider after its last moult.

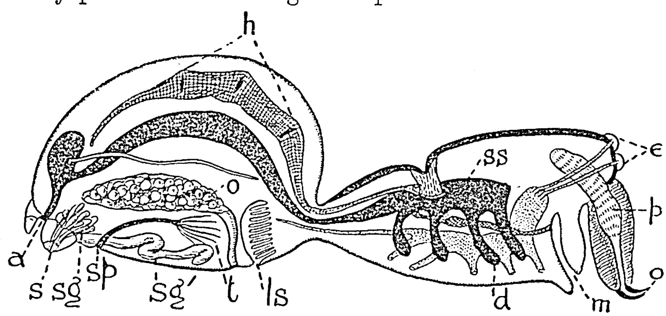

FIG. 135.—Diagrammatic longitudinal section through the body of a young *Epeira*.

a, Anus; *s*, spinneret; *sg* and *sg'*, silk glands; *sp*, spiracle; *t*, tracheae; *o*, ovary; *ls*, lung-sac; *h*, heart; *ss*, stomach; *d*, diverticulum of stomach; *e*, eyes; *p*, poison gland; *o*, opening of gland on mandible; *m*, mouth.

Habits. All through the summer, the spiders live on the food caught by the lady spider for her own consumption in the snare she weaves. This snare or web is constructed by her quite alone, the male taking no part in it, though he will at times carry off the food caught in it by his mate. Sometimes he will weave a small, rather imperfect web of his own, but his skill is far less than hers.

Her web is frequently made afresh each day in the summer during the most active weeks of her life, what remains of the old one being probably collected together into a ball and eaten before the new one is started, as Fabre noted in the case of the "Banded Epeira."[1] Fabre states that

[1] Not British.

he believes that no spider ever *mends* its broken web, but that *Epeira diademata* at any rate can do so, can readily be proved by breaking a few strands of the web, noting the position of the break carefully and then observing it the next day.[1] Young spiders are said to weave their snares in the daytime, but the old spiders work at night.

The Construction of a Web. The boundary lines. When about to start a new web, the spider begins by carefully laying down the strong boundary threads, to which the rest of the web will be attached. To make these—if she is working in such a spot that she can run round to the different points of attachment necessary for these threads—she merely presses her spinnerets against the first point, to fix a thread, and then walks off, drawing out more and more silken line as she goes, holding it carefully with one of her hind legs away from any object to which it might stick; when she has reached a point convenient for the attachment of the other end of the line, she stops, pulls the thread tight, and then fixes it by again rubbing the spinnerets against this second point. Usually at each end of the line the little divergent mass of threads mentioned above (pp. 203-4) can be seen, fixing the central thread to its supports. This line is then strengthened, for the spider walks along it and fixes another thread to it as she goes.

By repeating this process, several strong boundary threads are laid down, usually forming an irregular, four- or five-sided figure. These first threads may frequently stretch right across a window frame a yard or more in width; in fact, cases are recorded where they were three times this length.

The Spokes of the Web. The spider next starts on the construction of the web itself, fixing a thread near the centre of the top boundary line, and dropping with it, or carrying it round, to the centre of the opposite boundary, and fixing it there. The centre of this first diagonal is thickened with a little mass of silk and to this the radiating spokes will be joined. The spokes are first attached to one of the boundary threads, and then carried up a diagonal to the centre, drawn tight and fixed there, any surplus length being added to the central silken mass or "hub." This process is continued until there are sufficient radiating threads to

[1] *Life of the Spider.* J. H. Fabre.

support the spiral. The framework likewise is frequently strengthened by additional threads, binding it to fresh supports, so that it becomes very irregular in shape (Plate I.)

The Temporary Spiral. Then, starting from the centre, the spider first forms there a little irregular platform, and, from just beyond this, she starts a spiral line which is fixed to each spoke as it crosses it. The first line winds in a wide spiral of several turns, and is only a temporary scaffolding, to give foothold, whilst the spider finally lays down the very viscid spiral which constitutes the effective snare, in which insects are caught. All the previously formed threads dry in the air, so that they are not in the least sticky; the viscid substance now used for the snare is given out from special spigots on the last pair of spinnerets.

The Final Snare. The permanent spiral is begun at the circumference of the web, and is laid down with great care, each piece of thread being slightly stretched as it is fixed to the spoke it is crossing, and then suddenly released. It springs into its final position, and as it does so, the viscid fluid, which until now has covered it uniformly, is shaken into a series of little globules that hang on the thread, and can be seen distinctly with a lens, though invisible to the naked eye. Fabre[1] states that in the "Banded Epeira" which he studied these viscid threads are tubular and are tightly twisted, which gives them great elasticity. The tube is filled with the viscid substance, which gradually exudes, keeping the thread in good condition. The non-viscid spokes are simple, straight, solid threads.

As she lays down the viscid thread, the spider moves along the first non-viscid spiral, biting each piece away after she has made use of it.

The central dry platform she leaves unaltered, and there is often a fairly wide space between this and the viscid spiral (Plate I.). This non-viscid resting-place is doubtless convenient, though Fabre[1] says of another allied species that it does not stick even to the viscid threads owing to an oily exudation from the body. If this is removed from the legs by dipping them into carbon-disulphide, which dissolves the oil, the spider at once sticks.

The spider may often be seen resting on the central platform of her web, but more often she leaves it, carrying

[1] *Op. cit.*

with her a separate thread which she has fixed at the centre. When she reaches some safe retreat—perhaps under some leaves close by the web—she sits there, with her foot on the signal line which she has carried with her. A strong vibration of this will mean, probably, that some insect has been caught in the snare, and she will then hurry out to investigate.

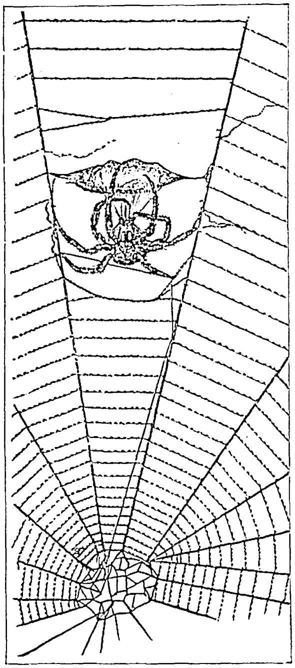

FIG. 136.—A Spider wrapping silk round a dangerous victim. (After Grant Allen.)

Treatment of Prey.

If the victim caught is a small one, it is at once killed by a bite from the poisonous jaws, and carried off to be eaten at leisure. If, however, it is too big and formidable to be treated so summarily, the spider approaches cautiously, cutting away some of the web if necessary, until the victim is dangling on a thread or two. She will then touch it carefully with one extended leg, and set it spinning round, and as it passes, fix on to its body a broad band of fine silk threads emitted by the spools, and wind it up in these until it is quite helpless, and can be seized with impunity (Fig. 136). Sometimes, when a dangerous insect, such as a wasp, gets entangled, the spider will set it free by biting away the threads all round it.

The Male Spider.

The male spider, as has been said, is smaller than the female, and generally lives more in the background. Indeed his life is in constant danger whenever he tries to approach his mate, for if not in a mood to receive him, she will dart out and attack him. At times she may even kill and eat him! His cautious courting of her may be seen fairly often. It seems to begin with telegraphic communications between them by means of vibrations of a thread of the web; then follows his cautious approach and

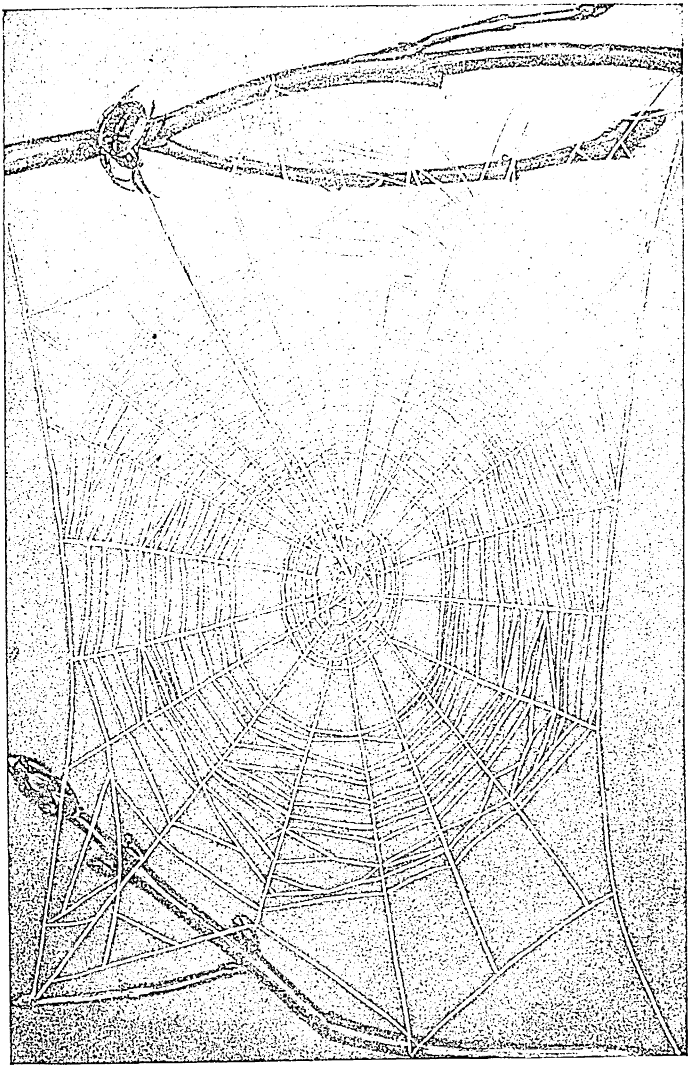

PLATE I.—*Epeira diademata* and Web.

rapid retreat if she seems unfriendly. He drops on a single thread of silk but soon climbs it again, once more to pay his addresses to her, until finally he attains his desire;[1] but even when he is accepted and saves his life, it is not of long duration, for he dies soon after mating.

Eggs. The eggs are laid in the autumn, some hundreds together, inside a round, bag-like mass of golden silk threads, which is fixed inside a crack in the bark of a tree, or under the cross-bar of a fence. This egg-bag, or egg "cocoon," as it is often called, may be $\frac{3}{4}$ of an inch in diameter. The young, bright yellow spiders may hatch out in a few weeks, but more often they remain dormant the whole winter. When they first emerge they cling together for about a week, in or close by the cocoon, forming a golden ball. If this ball is touched, the little "spiderlings" immediately drop a short distance on silk threads (Fig. 137) and then after a time climb up them again.

FIG. 137.—*Epeira diademata.* A swarm of young spiders dropping from a "cocoon."

The Young Spiders. Until they have moulted their first skins, the young spiders are unable to feed, but as soon as this is possible, they disperse, for they will no longer live peaceably together. If food is scarce they will frequently take to cannibalism! When first hatched they are yellow with a black patch on the abdomen and no white markings, but in most respects they resemble their parents; they only gradually, however, become fully mature, usually after about nine moults. When moulting, the spider assumes

[1] For an account of the courtship and mating of the "Angular Epeira" see Fabre's *Life of the Spider*. Also see *Courtship of Animals* by Pycraft, and observations by J. and E. Peckham, quoted by Prof. J. A. Thomson in *The Study of Animal Life*, chap. vi. (1917), from *Occasional Papers of the Natural History Society of Wisconsin*, vol. i., 1889.

first the attitude shown in Fig. 138, *a*; the skin then splits, and the spider wriggles its way out and drops as shown in Fig. 138, *b*, remaining thus suspended for some 15 minutes whilst the new skin hardens. When limbs have been lost, they are renewed at the next moult, though they are at first relatively small.

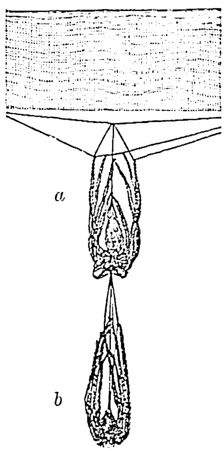

Fig. 138.—A Spider moulting: *a*, the empty skin; *b*, the spider. (After Grant Allen.)

Hibernation. Spiders, young and old, all disappear before winter, but though many perish, some survive after hibernating through the cold months. Under favourable conditions, they may live for two or three years.

Utilisation of the Silk. It was thought at one time that it might be possible to utilise the silk spun by spiders, in the same way as that of silkworms, and certain experiments have been made with the silk from the cocoons of the common Cross Spider, the cocoon silk being much stronger than that used in constructing the web. It was found, however, that though it was possible to use the silk—indeed certain stockings and mittens were actually woven of it—it was inferior in strength and quality to that of the silkworm. Also the spiders are exceedingly difficult to keep under control.

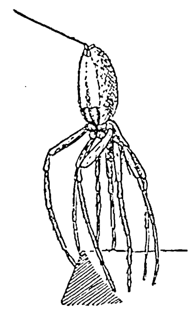

Fig. 139.—A young Spider preparing to go for a "fly." (After Emerton.)

Gossamer. When the young spiders first disperse in the autumn or spring, they do so in a curious way. They climb to some exposed point, and there each lifts its body as high as it can, standing on the tips of its feet. In this position it begins to exude silk from its spinnerets. The little mass of silk is soon caught on some slight current of air, and is drawn out until quite a long thread is floating in the air. When the wind catches this with sufficient

force, the spider seizes the thread with its claws and is wafted away, borne by the silk streamer. In this way voyages of considerable length may be made; and when it has had enough "ballooning," it is said that the spider can bring its travels to an end, by hauling in the thread with its legs and rolling it into a ball, so that it finally drops to earth from its own weight combined with that of the now tightly rolled up silk. It seems only possible for it to produce such free threads of silk when there are currents of air to draw them out. The spiders seen flying in this way in the autumn are of many different species; perhaps they are most commonly the young of *Lycosa* species (see p. 216), or of those small Theridiid spiders which live amongst the grass. When watching these spiders starting on their travels we recall how the same sight caused Walt Whitman to write:

A noiseless, patient spider
I marked where, on a little promontory, it stood isolated;
Mark'd how, to explore the vacant, vast surrounding,
It launch'd forth filament, filament, filament out of itself;
Ever unreeling them—ever tirelessly speeding them.

And you, O my soul, where you stand
Surrounded, surrounded, in measureless oceans of space,
Carelessly musing, venturing, throwing—seeking the spheres to connect them;
Till the bridge you need will be form'd—till the ductile anchor hold;
Till the gossamer thread you fling catch somewhere, O my soul.

Other True Spiders

There are many other spiders, differing somewhat in details of structure, and greatly in habits, but only a few can be mentioned here. It is convenient to group them provisionally according to their habits and the kind of snares they weave.

The Orb-weavers (Epeiridae). In such a classification, the Cross Spider, already described, would be included in a group of "Orb-weavers" (*Epeiridae*), because of the circular or wheel-like web it spins. This is a very large group, containing many British forms.

The Line-weavers (Theridiidae). Most of our British spiders are included in the group of the Line-weavers (*Theridiidae*). The web they make is a great contrast to that of the Orb-weavers, for in it very little art is displayed—it often consists merely of an irregular network of threads. In some

cases a horizontal sheet of threads is formed, with a loose network of threads in the bushes above it; insects get caught in the network and fall into the web, beneath which the spider is usually hanging, waiting for them. Such simple snares are to be seen at times spread out on gorse bushes or on low hedges. One very minute "Line-weaver" (*Theridion pallens*)

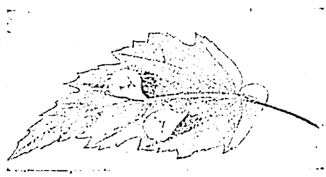

FIG. 140.—*Theridion pallens.* Egg-cocoons.

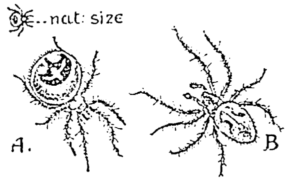

FIG. 141.—*Theridion pallens.* *A*, Female; *B*, male.

constructs a curious little white egg-cocoon, often to be found on the under sides of the leaves of various plants (Fig. 140). The cocoon is larger than the spider itself. The young spiders that hatch out often eat one another; only a small percentage is said to survive. The male and female *Theridion pallens* are shown in Fig. 141. The female spider is only about $\frac{1}{10}$ inch long.

The Cobweb-weavers (Agelenidae). The group of the "Cobweb-weavers" (*Agelenidae*) includes the Common House Spider (*Tegenaria domestica*) (Fig, 142), and also the spider, *Agelena labyrinthica*, which makes horizontal, concave sheet-webs amongst the grass or in hedges, with a silken tunnel running down from one corner, at the bottom of which the spider waits. These webs, like the cobweb of the house spider, are made of very fine threads and are not sticky at all. Belonging to the same family as these Cobweb-weavers, though living under very different conditions, is the Water Spider, which is described below.

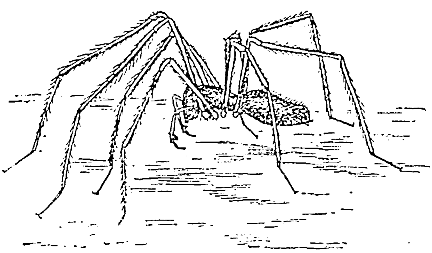

FIG. 142.—*Tegenaria domestica* (life size).

Water Spider (*Argyroneta aquatica*).

The Water Spider is fairly common in our ponds, and is a most interesting inmate of an aquarium, where, if supplied with a few long sprays of water-weed, she will soon begin to weave her very beautiful little web. This is at first horizontal, but in time becomes dome-shaped (Fig. 143, *N*) owing to the air which the spider brings down from the surface and discharges below it. This air is carried in a bubble adhering to the hairs on her abdomen (Fig. 143, *S*, *b*); sometimes she supports it also with her hind-legs, as she carries it down; finally she discharges it below her web by brushing it off with her legs. The bubbles rise and become entangled in the web, raising it, until—when sufficient air for the needs of the spider has been brought down—the web may have attained a shape such as that shown in Fig. 143, *N*, although it is not always so lofty as this.

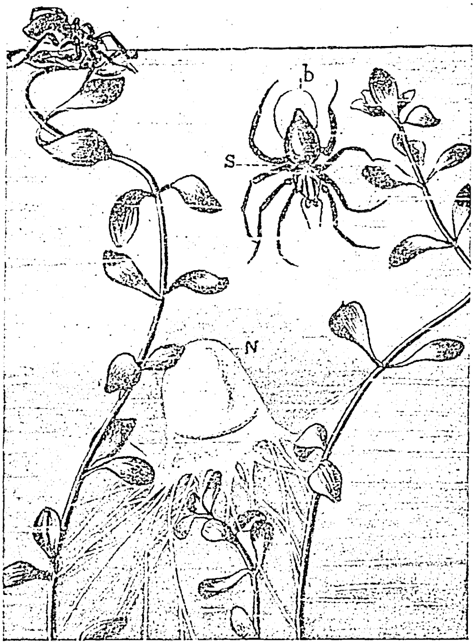

FIG. 143.—The Common Water Spider (*Argyroneta aquatica*).

S, The spider carrying down a bubble of air (*b*); *N*, the dome-shaped web or "nest."

This "web" is usually known as the spider's "nest," for it is not used as a snare, but as the lady spider's home, where she retreats when she has caught food at the surface

of the water, bringing it down to eat in peace in her little air-bell below. Late in the summer, she lays her eggs, separating off by a transverse wall of silk the upper part of the dome, to act as a "nursery." In a nest, very similar, but at a greater depth in the water and made of denser silk, she spends the winter in a more or less torpid condition.

For convenience in passing from place to place in the water, the spider weaves fine silk threads running from her "nest" to the surrounding weeds, and along these she runs with less effort than that needed in swimming. The male spider also constructs an air-bell, at any rate in the mating season, when it is to be found close by that of the lady spider. In the Water Spider, alone amongst spiders, the male is larger than the female.

The body of a water spider is covered with short hairs, making the surface like velvet; consequently air becomes entangled amongst the hairs, so that though the body looks black out of water, under water it looks as if surrounded by a globule of quicksilver and is a really beautiful object.

Running Spiders or Wolf Spiders (Lycosidae). Some spiders, though living on the ground, spin no web at all, but depend entirely on their hunting powers for obtaining sufficient food. The brownish-coloured *Lycosidae* are amongst these. Many of them hide themselves, when not hunting, in a little

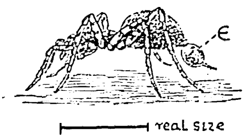

FIG. 144.—The Wolf Spider (*Lycosa picta*) carrying her egg-bag, *e*.

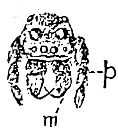

FIG. 145.—Head of the Wolf Spider seen from the front.
p, Pedipalp; *m*, jaw. (Much enlarged.)

burrow in the earth, lined with silk. From this they stealthily creep out, when the sun is shining, to stalk their prey, pouncing upon an unwary fly, and soon overcoming it by means of a bite of their poisonous jaws. It is then carried off to the home burrow and devoured at leisure.

Good sight is necessary for success in hunting, and the form and arrangement of the eyes are peculiar in this group (Fig. 145). Four small eyes, just above the jaws, look forwards; above these, two relatively large eyes gaze out also

in front, whilst two more eyes, one on each side of the top of the head, keep a look-out upwards.

The female wolf spider (*Lycosa*), in the breeding season, always carries with her a little, light-brown or grey, spheroidal bag of eggs, which remains attached below her spinnerets until the young ones hatch out, when they climb on to their mother's back, often completely covering her, and here they are carried for some months, gradually dropping off and beginning life for themselves. During the winter they lie hidden under stones or in some crack or crevice. In spite of an apparently striking display of maternal care for her eggs and young, the "Narbonne Lycosa" has been shown by Fabre to exhibit a curious lack of intelligence, for if her bag of eggs is taken away from her and a ball of pith or cork of the same size and shape given her in its place, she will adopt this and show as much maternal solicitude for it as for her own eggs. For example, every morning she will climb out of her tunnel on to the little stone parapet which she has built round its mouth, and there she will place herself with her head inwards, and with her back legs outstretched to hold up the little ball to the sun, turning it round and round so that all sides get their share of warmth, a custom of undoubted advantage to the little developing embryos within the eggs, but very misplaced energy in the case of a mere pith ball; she will do this for three or four weeks, abandoning the ball, however, when the hatching time arrives with no result.[1]

Lycosa saccata is a very common wolf spider; it has a yellow-brown body with darker markings, and a pale-brown egg-sac.

Lycosa picta is found on the sandhills by the sea-coast or on sandy commons inland; it is of a reddish-brown colour with deeper stripes. It makes little burrows in the ground, excavating and carrying out the earth with its jaws. The burrow is Y-shaped, with one rather longer arm coming to the surface of the soil, but the other arm and the stem of the Y ending blindly.[2]

Lycosa pirata (the Raft Spider) is a wolf spider that is often found on the surface of the water in June, though

[1] *The Wonders of Instinct*, by J. H. Fabre.
[2] *Spiders*, by C. Warburton (Camb. Univ. Press, 1912).

living by the water edge. The poisonous *Tarantula* is a large wolf spider of South Europe.

The Jumping Spiders (Attidae or Salticidae). The Jumping Spiders also form no snare, but wander about stalking their prey, or jumping suddenly on to it as it approaches their hiding-place. They usually leave a silk thread behind them which attaches them to the spot whence they sprang—a custom which frequently saves them from a fall when hunting, as they so often do, on walls and fences.

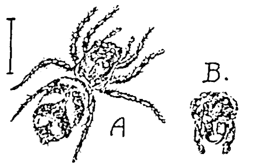

FIG. 146.—The Zebra Spider (*Salticus scenicus*).
A, Dorsal view of spider; *B*, head seen from the front. The line on the left shows actual length.

These spiders do not carry their eggs with them, but deposit two or three little white cocoons in silken nests in some crack or corner.

The commonest British jumping spider is *Salticus scenicus*, a small form with a black body, with white "zebra" markings both on the body and on the rather short, haïry legs. The female is about $\frac{1}{4}$ of an inch long, the male rather smaller. The arrangement of the eyes differs from that in the wolf spider; four are large and look forwards, the other four are placed on the top of the head in two rows and look upwards, the central two being very small.

The ways of these spiders at the courting time are well worth watching. The males go through most curious dancing antics before the female they wish to captivate.

The Trap-door Spiders (Aviculariidae). The Trap-door Spiders form beautiful little silk-lined tunnels in the ground, closed at the surface by hinged lids. These spiders are not found in Britain, though they occur plentifully in South Europe.

The Drassid Spiders (Drassidae). The Drassid Spiders are very common in Britain. They are large, dull-coloured, brown spiders, often to be seen on turning up a stone or pulling a piece of loose bark from a tree. They can usually be quickly recognised by the position of the spinnerets, which project from the end of the body, and so can be seen from above (Fig. 147).

There are eight eyes in this spider also, but they are in two rows only. The body of the male spider is nearly $\frac{1}{2}$ an inch long.

The Money-spinners (Erigoninae). The Money-spinners (*Erigoninae*) are the very numerous, minute, dull-coloured forms to which is largely due the "gossamer," so plentiful in autumn.

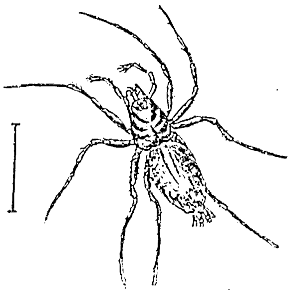

FIG. 147.—*Drassus lapidosus.*

The Crab-Spiders (Thomasidae). There are many British Crab-Spiders; they are small forms, with legs usually all projecting laterally, instead of with two pairs pointing forwards and two backwards, as in most spiders. Many have a rapid sideways mode of progression that is distinctly crab-like. These spiders lie in wait for their prey inside flowers or in bushes. *Misumena vatia*, the "Flower Crab," is a brightly coloured little spider of rather variable hue. The female is about $\frac{1}{3}$ of an inch long, and has a milk-white, yellow, or green abdomen, often adorned with a bright crimson mark on each side; the male is smaller and darker.

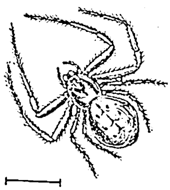

FIG. 148.—The Flower Crab (*Misumena vatia*).

Order II.: PHALANGIDEA (THE HARVESTMEN)

The Harvesters, or Harvestmen, are often mistakenly called spiders, from which they differ widely in the form of the body. In them there is no constriction between fore and hind body, and also the abdomen is clearly segmented and bears no spinnerets. They breathe by tracheae only, two spiracles opening near the base of the fourth pair of legs.

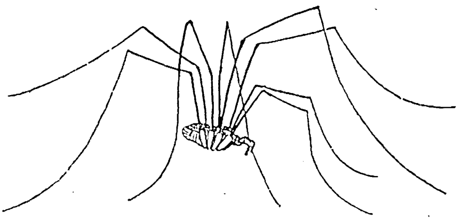

FIG. 149.—The Common Harvestman (*Phalangium opilio*).

The Common British Harvestman has an almost spherical body and very long legs. It frequently loses a leg, but seems little disturbed by the loss. Harvestmen feed on *Aphides* and small insect grubs. The females lay their naked eggs in holes in the ground, or under stones.

Order III.: ACARI (MITES)

Acari or "Mites" are usually minute Arachnids in which the unsegmented abdomen and the thorax are united by a broad junction.

The larva at first has usually three pairs of legs (except in the Gall-mites), but acquires four pairs before becoming adult.

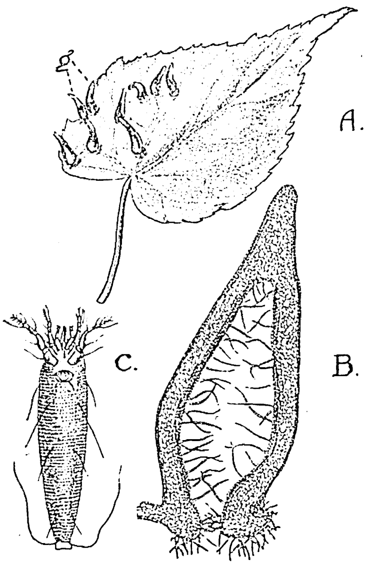

FIG. 150.—Lime leaf with Gall.
A, Lime leaf with "Nail Galls," *g* (nat. size); *B*, a longitudinal section through one Nail Gall (enlarged); *C*, one Nail Gall Mite (much enlarged). (*Eriophyes* (*Phytoptus*) *tiliae*.)

Some of the Acari have a much elongated, striated abdomen; these are the **Gall-mites** which produce little finger-like or pimple-like processes on the leaves of some trees, *e.g.* the "Nail Galls" on the lime (Fig. 150); also the "Red Pimple" galls on sycamore and maple, sallow willow and alder. Again, the swollen arrested buds and distorted catkins sometimes found on hazel are due to *Eriophyes avellanae* (Fig. 151), and the distorted buds on yew to *E. taxi*.

The Gall-mites are unlike other mites in having only two pairs of legs, which are placed very close to the head; the mouth-parts are capable of biting. The galls have only one single chamber, which is open below, the opening being guarded by hairs. In this cavity many mites live together,

feeding on the hairs produced from the inner lining of the gall-cavity.

Demodex is a long-bodied form, rather like a gall-mite, but with four pairs of legs, which causes the disease known as "demodic mange" in dogs.

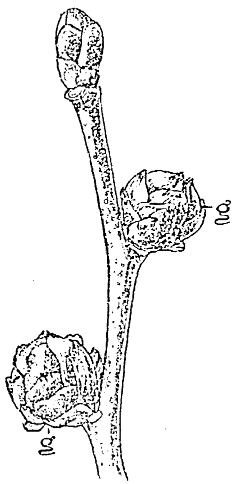

FIG. 151.—A hazel twig with two swollen buds (*g*) infected by a Gall-mite.

Other mites, eyeless and with short bodies and no tracheae, live on various animal and vegetable matter, *e.g.* the minute soft-bodied **Cheese-mites** (*Tyroglyphus*) which feed on cheese, and the **Itch-mites** (*Sarcoptes*) which attack various mammals including man—*Sarcoptes canis* is the commonest cause of ordinary mange in dogs.

Harvest-mites in their larval stage are the Harvest-bugs (*Trombicula*) that attack man, burrowing below his skin and causing a troublesome irritation (best allayed by the application of ammonia). They are barely visible to the naked eye. The adult form is not yet identified with certainty.

Ticks feed on the blood of various mammals and birds; there are pigeon-ticks and fowl-ticks (genus *Argas*), cattle- and horse-ticks (*Ixodes*), and others.[1]

Acarapis woodi is the mite which lives in the thoracic tracheae of hive bees, causing the "Isle of Wight disease."

The Water-mites (*Hydrachna*) are larger and fairly common in ponds. The little Scarlet Water-mite is rather less than $\frac{1}{8}$-inch long; it is a very active swimmer; its larvae suck the blood of water insects and spiders, but the adult feeds on minute Crustaceans.

Classification of the Arachnida mentioned in Chapter XIV.

Order I. ARANEAE (The True Spiders).

(1) Epeiridae. The Orb-weavers.

Epeira diademata, the Common Cross Spider.

[1] For further details of all these parasitic mites, see British Museum, *Economic Pamphlets*, Nos. 6 and 13.

Q

(2) Theridiidae. The Line-weavers.
Theridion pallens.

(3) Agelenidae. The Cobweb-weavers.
Tegenaria domestica, the Common House Spider.
Agelena labyrinthica, the Labyrinth Weaver.
Argyroneta aquatica, the Common Water Spider.

(4) Lycosidae. The Running Spiders or Wolf Spiders.
Lycosa picta. The Common Wolf Spider.
Lycosa pirata. The Raft Spider.
Lycosa saccata.

(5) Salticidae (= Attidae). The Jumping Spiders.
Salticus scenicus, the Zebra Spider.

(6) Aviculariidae. The Trap-door Spiders.

(7) Drassidae. The Drassid Spiders.
Drassus lapidosus, the Stone Drassid.

(8) Erigoninae. The Money-spinners.

(9) Thomasidae. The Crab Spiders.
Misumena vatia, the Flower Crab.

(10) Dictynidae. The Cribellate Spiders.
Amaurobius.

Order II. PHALANGIDEA (The Harvestmen).

Phalangium opilio, the Common Harvestman.

Order III. ACARI (The Mites).

Eriophyes tiliae, the Nail Gall on lime.
E. macrorhynchus, the Pimple Gall on sycamore.
E. taxi, the Bud Gall on yew.
E. avellanae, the Bud Gall on hazel.
Demodex canis, Demodic Mange Mite.
Sarcoptes canis, Sarcoptic Dog Mange Mite.
Sarcoptes scabiei, the Itch-mite.
Tyroglyphus siro, the Cheese-mite.
Trombicula sp., the Harvest-bugs.
Ixodes sp., Cattle-tick.
Argas sp., the Pigeon-tick and Fowl-tick.
Acarapis woodi, the "Isle of Wight Disease" Mite.
Hydrachna, the Red Water-mite.

PRACTICAL WORK ON ARACHNIDA

1. In September, hunt for Common Cross Spiders in the garden. Watch the formation of the web and the snaring of flies in it.

Whenever a web is found, look for the spider belonging to it, following the control thread from the centre of the web up to the spider's hiding-place. Experiment by putting different objects into the web and watching what happens. Another time cut the "communication cord" before putting the prey in the web and note the result. Remove a piece of the web by pressing a piece of glass against it; it will then adhere and can be examined under the microscope. Note any difference between the viscid and non-viscid threads. In October and November, search for the cocoons of eggs, and keep them until the eggs hatch.

2. Bring one spider indoors, enclosing it for a short while in a small glass tube. (The cork should be pierced to admit air.) Examine with a lens, make out all the main facts of external structure. Sketch the spider in different positions.

3. Suspend the spider from the end of a twig and examine the threads which issue from the spinnerets. Let it fall some distance from the twig, on its thread; then touch it and observe the way in which it climbs the thread, rolling it up into a ball as it goes.

Fix the twig upright in a dish of water; the spider will run down, but finding it cannot escape, it will probably mount the twig again and give out a silken thread, which (if the stick is in a draughty place) will grow longer and longer, and will finally catch on to something. The spider then quickly pulls the thread tight, fixes her end, and escapes over the "suspension bridge" thus formed. If the stick is set up in a very sheltered spot (covering it with a bell-jar would suffice) it will be found that the spider is incapable of emitting this thread.

4. In spring, look for clusters of newly-hatched spiders; note how they differ in colouring from the adults; observe their habits.

5. Collect some *Labyrinth spiders* from the country-side in the laying season (*i.e.* mid-August) and confine them each in a large gauze-covered cage with a damp earthen floor and some twigs of thyme or other plant on it. Supply the spiders with plenty of insect food. Watch the construction of the labyrinth and brood cocoon. Drops of water should be sprinkled in the cage occasionally.

6. If a *Hunting spider* (*Lycosa*) is found, dragging along an egg-bag, remove this carefully with forceps and offer her instead a ball of pith or cork; also offer her her own eggs again at varying intervals of time and see how long her interest in them is maintained. Compare results with those given by C. Warburton. Read Fabre's account of the "Narbonne Lycosa."

7. With a dipping-net secure a few water spiders from a pond or river, and bring them home; they will thrive in a tank, if fed with an occasional dead fly. The tank must be covered so that they cannot escape. The spiders will readily construct their thimble-shaped "nest," and the whole process of weaving it and filling it with air may be watched.

8. Search for spiders of other kinds and for Harvestmen in garden and field, and watch their ways in their natural habitat. Identify them by reference to *British Spiders*, by E. F. Staveley (1866), or *The Spiders of Great Britain and Ireland*, by J. Blackwall (1864). Read *Spiders*, by C. Warburton (Camb. Univ. Press, 2s.); also *Life of the Spider*, by J. H. Fabre.

9. During the summer, look out for lime leaves with nail galls on them. Examine them at different times during the summer, and try to trace the life-history of the gall-mite inhabiting them. A microscope and some section-cutting will be necessary.

Examine also the various pimple-galls due to Mites, to be found on the leaves of various trees.

Class III.: MYRIAPODA

The members of this little group of Arthropods breathe by tracheae like insects (see p. 234), but they differ from them in the form and internal structure of their bodies, and also in the many pairs of appendages which specially characterise them. They live in dark and moist spots, running or wriggling over the ground, or hiding in rotten wood or under a stone. The body of a Myriapod is of much the same width throughout, and there is no marked distinction between thoracic and abdominal segments, each of which is covered by an exoskeleton of chitin, with, in some cases, lime deposited in it. Each segment has, as a rule, one or two pairs of jointed appendages attached to it.

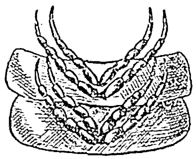

FIG. 152.—Two segments of *Polydesmus*, a Millipede. Ventral view to show the attachment of the legs.

The class Myriapoda is conveniently divided into two orders, which contain respectively the Millipedes and the Centipedes.

MILLIPEDES (CHILOGNATHA)

Millipedes have cylindrical bodies and short antennae (Fig. 153, *J*); they are slow-moving, inoffensive little

creatures, with hard, scaly skins of chitin and lime forming a ring round each segment of the body.

Most of the segments, except the first three and the last, have two pairs of legs; the first three have generally only one pair of legs apiece, and the fourth may be legless, as is usually the seventh also, in males. Millipedes feed on plants. When handled they may give out a bad-smelling fluid from

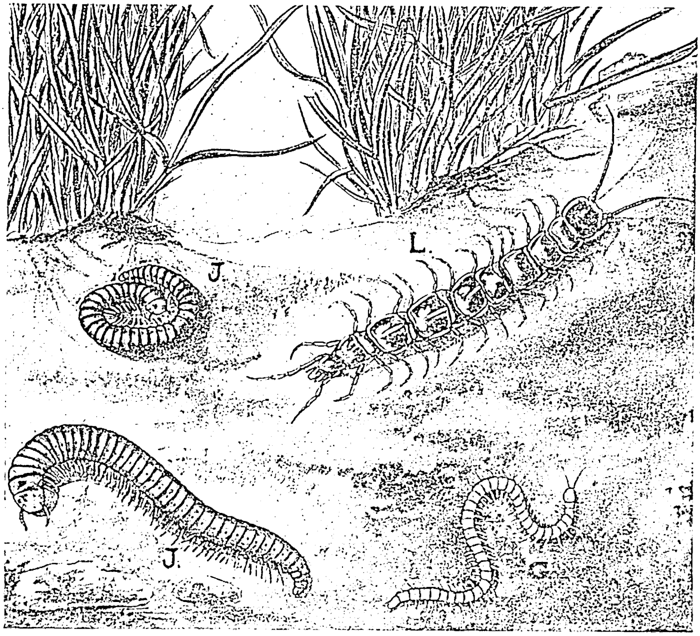

FIG. 153.—Some common Myriapoda.
J, Julus; *L*, Lithobius; *G*, Geophilus.

special glands in the body. When they hatch from the eggs they have only three pairs of appendages, namely, the antennae and two pairs of jaws; the walking legs all develop later, appearing in batches. This is well seen in *Julus*, the form described below, where new segments and new sets of appendages appear in sets of five at a time, between the end segment and the last but one. Five new segments, still without legs, are shown in the specimen drawn in Fig. 153, *J*.

Julus. The most common British Millipede is the "False Wireworm" or Snake Millipede (*Julus terrestris*) (Fig. 153, *J*), a shiny, smooth form, stiff and slippery to the touch, and curling up rapidly when disturbed into a flat spiral, as shown in the figure. There are about thirty segments to the body, and the head bears on either side a little cluster of eyes.

Julus[1] can readily be kept in captivity, and will breed in the early summer months. The eggs are laid in a little cell hidden in the earth; this cell is about the size of a small nut, and formed of earth particles made to adhere together with saliva. Into it, 60 to 100 small eggs are passed by the mother *Julus*, through an aperture at the upper end, which is afterwards closed with earth. The eggs hatch in about twelve days; the larvae have at first only a few segments and 3 pairs of legs, the others appearing during successive moults.

These Snake Millipedes sometimes do serious damage in seedling beds, feeding on the soft young tissues. It is well to divert their attention from these by putting down a few potatoes to attract them, and then when a number have collected in them, they can be removed and destroyed if necessary. In ordinary beds of plants, however, they feed mainly on decaying vegetation.

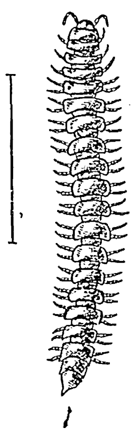

Fig. 154.—*Polydesmus*, a common Millipede.

Polydesmus. Another Millipede not so common as *Julus*, but sometimes found many together, is *Polydesmus*, in which the cylindrical body has only nineteen or twenty segments and no eyes (Figs. 154 and 152).

Centipedes (Chilopoda)

Centipedes differ from Millipedes in having flattened bodies with only *one* pair of legs to each body segment; also they have longer antennae with at least fourteen joints. They are active, fierce little creatures, feeding on animal food. They stalk their prey and then kill it with the strong, poisonous first pair of legs, which lie just below the mouth.

[1] *Camb. Nat. Hist.*, *Insects*, Part I.

Lithobius. *Lithobius forficatus*, or "Thirty-legs," may be found in most gardens, hiding in corners under stones or leaves. It has a flattened, dark-coloured body with fifteen segments, and fairly long, strong legs, on which it runs swiftly over the ground (Fig. 153, *L*). The movement of these legs is very difficult to follow, and it was the consideration of this problem which inspired the following lines, quoted by Professor Ray Lankester in *Nature* (1889):—

A Centipede was happy—quite !
Until a toad in fun
Said, "Pray which leg moves after which ?"
This raised her doubts to such a pitch,
She fell exhausted in the ditch,
Not knowing how to run !

Geophilus. A Centipede common in the south of England is *Geophilus*, a long-bodied, light-coloured, wriggling form (Fig. 153, *G*). This creature has often over 100 segments to its body. It has no eyes. The young, which hatch from eggs laid in the ground, have from the beginning their full number of legs. Some Geophilidae are "phosphorescent," or, rather, they shine at night with a luminous glow.

Classification of Myriapoda mentioned in Chapter XIV.

Order I. CHILOGNATHA (Millipedes).
(Forms with two pairs of legs on most of the body segments; they feed on plants.)
Julus. Polydesmus.

Order II. CHILOPODA (Centipedes).
(One pair of legs on each body segment; carnivorous.)
Lithobius. Geophilus.

PRACTICAL WORK ON MYRIAPODA

Collect various specimens and isolate the different species in "terraria" such as that described in Appendix E, giving them earth in which to burrow and their appropriate food—the chief thing to guard against is drought. Make careful observations and records of their habits. Mr. Sinclair, writing in the *Cambridge Natural History*, observes that "the habits of the Myriapods connected with their breeding are most interesting, but have been very insufficiently investigated. There is no doubt that a full enquiry into all such habits would be of great interest, and would help to answer some of the problems which are still unsolved in these forms."

CHAPTER XV

ARTHROPODA (*continued*)

Class IV.: INSECTA

General Characteristics. INSECTS share with birds the domain of the air, and their adult structure is specially adapted to this aerial life. At the same time, they all undergo metamorphosis in their development, and the larvae are very varied in their lives, some being adapted to aquatic life, as the caddis larva; others to life underground, as the cockchafer grub; others, such as caterpillars, to a life above ground, but sheltered by vegetation; and finally there are those that live a passive larval life, cared for by the adult insects, as in the case of the larvae of ants and bees. A considerable variation is to be seen, therefore, in the structure of the larvae, and special larval organs are frequently developed which are not to be seen in the adult; all the larvae are alike, however, in having a segmented body,

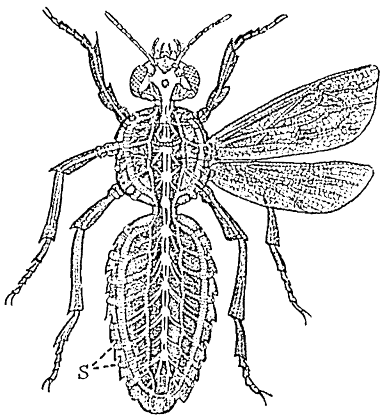

FIG. 155.—Diagrammatic dissection of an Insect's Body. (After Schmeil.)

To show (1) The head with mouth-parts, eyes, and antennae; (2) The thorax of three segments bearing wings and legs; (3) The abdomen. Down the centre of the body is shown the nervous system, and on either side the tracheae (marked with transverse lines) and the spiracles, *s*.

and in having no power of flight. A very large majority of insects, when adult, possess wings and can fly. Fig. 155 shows diagrammatically the general structure of the body of an adult insect.

Divisions of the Body. In all the higher insects, the division of the body into three regions—head, thorax, and abdomen—is very distinct.

The *head* is relatively small, but is very firm and compact. It bears (1) a single pair of jointed antennae which are the special tactile sense-organs; (2) three pairs of modified appendages round the mouth, the so-called "mouth-parts"; (3) a pair of large compound eyes (see p. 231). Assuming that each pair of appendages corresponds to one segment of the primitive form, the head is formed of at least four fused segments, and many zoologists think that more than these have gone to its construction; however, no other signs of segmentation in it are visible externally. It is separated from the thorax by a narrow neck, which is largely membranous, and can be extended, or folded so that the back of the head is overlapped by the first thoracic segment. The head has, therefore, great freedom of motion.

The *thorax* consists typically of three segments, the divisions between which can often be easily seen. It bears ventrally three pairs of jointed appendages, the legs, and dorsally, attached to its two hinder segments, are usually two pairs of membranous wings, though one pair may be absent, as in flies, or the first pair may be modified into hard sheaths, as in beetles. To this thoracic region, therefore, are attached all the organs of locomotion, and it must necessarily be broad and strong, to allow for the presence and attachment of the strong muscles which move the wings and limbs.

The *abdomen* is more distinctly segmented than the thorax, and is not so compact and hard. It bears no appendages except at the tip, where occasionally a pair of jointed feeler-like processes is present (see p. 299). In the case of some female insects, there may be at the end of the abdomen a sharply pointed tube, the "ovipositor," which is used in depositing the eggs in the place where they are to be hatched, often within the tissues of a plant. Sometimes, again, there may be paired stinging or piercing organs present just within the end of the body. The number of segments in the

abdomen varies, and in any special case is often difficult to determine exactly, for the last one or two segments are often much modified and sometimes withdrawn within the other segments. The most usual number is ten.

One or two segments of the abdomen may be very narrow, and form a kind of waist, as is seen very markedly in ants, where these modified segments, connecting the thorax with the much swollen hind part of the abdomen, are known as the "nodes."

Leg Structure. The legs of insects usually have a constant number of joints with five distinct parts. Next the body comes a short segment, the "*coxa*," then another short piece, the "*trochanter*," next the long "*femur*" and the "*tibia*," the two longest segments of the leg, and finally the part known as the foot or "*tarsus*," which is itself formed of from one to five segments, five being the most frequent number. The last segment bears a pair of curved claws, and may also bear, between the claws, a lobe modified for a special purpose (see p. 369).

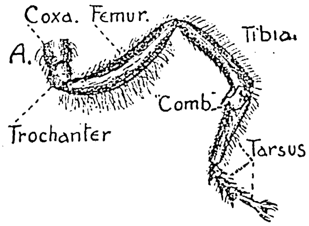

FIG. 156.—The front leg of a Bee.

Mouth-parts of Insects. The mouth is always overhung by an "upper lip" or *labrum*, which is an overhanging flap of the chitinous covering of the head. Below the labrum is a pair of unjointed, hard, biting jaws, known as the "hard jaws" or *mandibles.* These vary greatly in size in the different orders of insects, reaching a maximum development in the male stag beetle, where they are as long as the whole of the rest of the body. Below the mandibles is a pair of complex "soft jaws," or *first maxillae*, jointed structures with several branches, the most conspicuous of which lies on the outer side, and is known as the *maxillary palp* (Fig. 157). This sometimes bears a special sense-organ at its apex, as in the case of the Large White Butterfly. The other lobes of the maxillae serve the purpose of holding the food whilst it is being eaten. One other pair of appendages, the *second maxillae*, seems to be represented in the head, but fused together to form the median structure known as the *labium*

or "lower lip," which bounds the mouth on the lower side. The labium also bears a pair of processes known as the

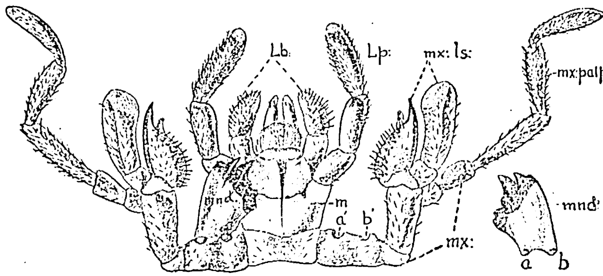

FIG. 157.—The Mandibles, Maxillae, and Labium of a Cockroach.
mnd, Mandibles (*a b* has been removed from *a' b'*); *mx*, maxilla; *mx.ls*, maxillary lobes; *mx.palp*, maxillary palp; *m*, mentum bearing the labial palp, *Lp*, and the labium, *Lb*. The central lobe of the labium, the lingua, can be faintly seen.

labial palps, and attached to it is a central lobe known as the *lingua* or *tongue*.

In different insects, with different feeding habits, these various mouth-parts become modified to suit the food in each case, but always the same parts can be recognised, namely, the single upper lip (labrum), the pair of hard jaws (mandibles), the pair of soft jaws (first maxillae), and the lower lip, or labium, with its palps.

The Eyes of Insects. Of all the special structures found in insects, the most peculiar and wonderful are perhaps the large compound *eyes*, which are present in all adult insects, although simple eyes may also occur. Compound eyes also occur in a few im-

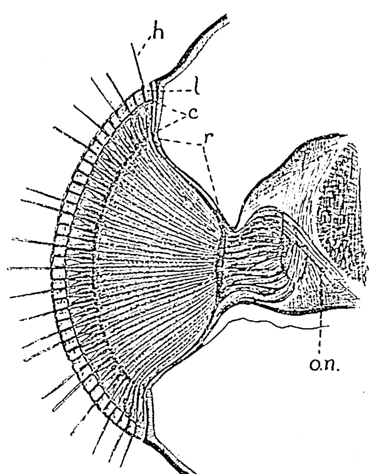

FIG. 158.—Section through the eye of a Bee.
o.n., Optic nerve; *l*, lens; *c*, cones; *r*, rods; *h*, hair.

mature insects, *e.g.* in the larvae and nymphs of Dragon-flies and May-flies and in the larvae and pupae of the Phantom-fly. These compound eyes project, one on each side of the head, as sessile, convex, immovable structures, the surface of which, when examined with a lens, is found to be marked off in a very large number of little hexagonal or square areas or facets. A microscopical examination of a section of the eye (Fig. 158) reveals the fact that underneath each facet there lies a series of structures, forming a long, narrow, pyramidal body, which is in itself a complete organ of vision, though, owing to its minute size and structure, it has a very limited range, and needs, therefore, to be supplemented by the other similar visual elements surrounding it.

The exposed facet (Fig. 159, *f*) is the outer end of a glassy columnar body, the *lens*, beneath which is a transparent *cone* (Fig. 159, *c*), and beneath this, again, a *rod*-like structure, which is surrounded by a delicate sheath in connection with a branch of the optic nerve. This sheath acts as a retina, and receives the impressions of the rays of light which enter the facets and pass down the cones and rods. Each such set of parts in the eye is separated from the adjacent parts by a sheath of dark-coloured pigment, which is specially concentrated just at the bases of the cones (Fig. 159, *p*), and again at the bases of the rods.

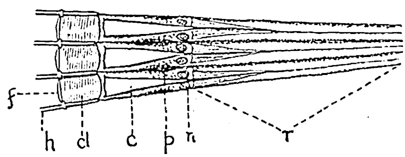

FIG. 159.—Three visual elements of the eye of a Bee enlarged.

f, Exposed facet of the element; *h*, base of hair; *cl*, corneal lens; *c*, cone; *r*, rod; *p*, pigment shown by black dots; *n*, nerve cell.

Many thousands of such elements as those described go to make one compound eye, the number of them varying in different insects. The *mode of vision* of such an eye is not very certainly understood. It seems clear, however, that only those rays of light which enter each facet at right angles to its surface reach the base of the eye, for all obliquely entering rays are absorbed by the pigment sheath. Probably, therefore, only a few rays from any one point of an object enter any one lens in such a way that a reduced image of it is formed on the sensitive retina; the rays from an adjacent

point of the object enter an adjacent lens, and form the corresponding image on an adjacent part of the retina. In this way the complete image, formed at the back of the eye on the retina, will be a mosaic of a number of partial images each formed by a different lens. Experiments made by Dr. Wager seem to show that whilst the outer lenses form partial, reversed images of an object, the crystalline cones rectify this confusion by again reversing the images so that one complete picture results. In whatever way the image may be produced, such a projecting compound eye is evidently a very effective organ for warning its possessor of the approach of any object, for an insect is very difficult to surprise.

Simple eyes, or *ocelli*, are also very frequently found in adult insects, and in the larval stage they are generally the only eyes present. They are quite simple in structure, consisting sometimes merely of a mass of pigment lying over a nerve end, though most frequently over the pigment patch is a small transparent lens serving to focus the light on to it. Müller suggests that these ocelli are chiefly of use in dark places and for near vision; they are specially developed in ants, bees, and wasps, and in night-flying moths.[1]

Other Senses. The sense of *taste* is lodged in little sensory pits on the mouth-parts.

No organ of *hearing* is known, though, since insects make sounds, it is reasonable to think that probably they can hear. These sounds are usually made by the rapid vibration either of the wing or of little chitinous membranes stretched behind the spiracles which quiver as the air passes in and out.

The sense of *smell* seems well developed, and is said to be concentrated in the antennae, which bear small pits lined with sensory hairs.

J. H. Fabre's wonderful experiments with moths and beetles and other insects seem to show that this sense is of two kinds. To a large extent they smell as we do as the result of the stimulation of the olfactory nerves by actual contact with emanations from the object smelt, actual particles which volatilise and diffuse through the air. But beyond this they seem to perceive odours to which we are entirely insensitive, and which Fabre's ingenious experiments lead him to think must be due to vibrations in the ether which are

[1] *Physiology of the Senses* (Müller).

not of the right intensity to affect the visual nerves, but which stimulate in a remarkable way some special olfactory sense, in some insects at any rate, so that, to give two examples only, the male Oak Egger or Banded Monk moths hastened in numbers from miles around to the waiting female hidden in his study; and unerringly the little Bolboceros beetle detected the presence of its chosen food, the Hydnocystis fungus growing hidden 8 or 9 inches below the surface of the soil, and sank a little vertical shaft down to it.[1]

Respiration of Insects.

All adult insects breathe in atmospheric air through small openings or *spiracles*, several of which are usually to be found on each side of the body. These spiracles lead into a complex system of *air-tubes* or *tracheae* (Fig. 155) which carry the air to all parts of the body, forming a regular network of minute tubes round the internal organs, aerating them directly. No blood-vessels therefore are needed to act as air-carriers and the blood-vascular system is much reduced; it consists merely of a long tubular contractile dorsal vessel or heart which drives the blood into a number of blood spaces or "sinuses," whence it is returned to the pericardial sinus. The blood probably functions mainly or solely as a food-carrier.

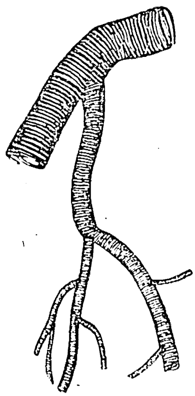

FIG. 160.—A small piece of the trachea of a Bee.

The tracheae are the oxygen-carriers, but it is not certain that they also act as the agents for removing carbon dioxide. It is suggested that since the characteristic chitinous skin of insects consists largely of carbon and nitrogen, the secretion and casting off of this may be the normal means of getting rid of waste carbon and nitrogen.

The wall of each trachea is strengthened, on its inner side, by a chitinous spiral thread, which serves to keep the cavity of the tube open, so that the air can pass freely along (Fig. 160). The renewal of the air in these air-tubes seems frequently to be brought about by rhythmic movements of the abdomen, sometimes accompanied by the alternate closing and opening of the spiracles.

[1] *The Life of the Caterpillar*, by J. H. Fabre, chaps. xi., xii., and xiii.

In aquatic insect larvae the spiracles are often closed, and the tracheae may be continued externally as thin-walled, tubular processes known as *tracheal gills* which absorb the air dissolved in the surrounding water.

Wings of Insects. The wings, of which there are usually two pairs in the adult, consist of two thin, membranous plates, which adhere together and are united all round the free margin. Each wing has, running through it, harder, horny lines known as the "veins," "nerves," or "nervures" of the wing. The arrangement of these varies in the different orders of insects, but is fairly constant within each order, and therefore this character is made use of in classifying them. The horny nervures are hollow tubes, inside which blood-cells and tracheae have been demonstrated. The nervures always enter the base of the wing as two or three large stems, which branch and branch again, until they may form as intricate a pattern as that seen in the Dragon-fly. The variations in structure and development of the wings will be studied in further detail later.

Meta-morphosis. The metamorphosis during the development of most insects is very striking. From the egg there hatches a little larva, which is, in many cases, very unlike the adult. This is specially so where the food and habitat differ in the different stages of development. In such cases the larval form, which is always wingless and may also be legless, as in the grubs of bees, or maggots of flies, is retained until growth is complete, the growth being accompanied by a series of skin moults. Then the full-grown larva may enter upon a resting, quiescent stage known as the *pupal stage*, or as the *chrysalis* in the case of a butterfly. In this stage the creature is usually motionless and ceases to feed, whilst certain important internal changes take place, leading to the perfecting of the special adult organs. When this is complete, the skin is cast for the last time, and the winged, adult creature, or *imago*, emerges. Such a series of changes, including a quiescent pupal stage, is known as a "complete metamorphosis." In some insects there is no pupal stage, the change from larva to imago taking place gradually throughout the larval life, with a sudden, greater change becoming apparent at the last moult, as for example in dragon-flies. Such a development is known as "incomplete metamorphosis,"

and the developing larva, as soon as signs of wings are visible externally, is known as the *nymph.*

The changes that take place internally during the pupal stage vary. The phenomenon is strangest in such forms as the Blow-fly. Here the full-grown maggot detaches its outer skin, which hardens into a kind of capsule or cocoon, and inside this the whole body disintegrates into a creamy mass within a delicate membrane, and from this shapeless mass in a few days there gradually evolves the intricate body of the perfect blow-fly.

Classification of Insects. The Insecta are grouped into orders according to the number and texture of the wings, the modification of the mouth-parts, the nature of the metamorphosis, and the form and habits of the larva and pupa.

The great variation in structure and type of metamorphosis amongst members of this class make the recognition of their relationship rather difficult, and we are still awaiting a completely satisfactory classification of them. In the meanwhile the following, based on that given by G. H. Carpenter in his *Insect Transformation,* may be followed.[1]

Sub-class I.: APTERYGOTA[2]

Forms which are always wingless and which undergo little, if any, metamorphosis. They have three pairs of legs and, usually, well-developed antennae. These forms have more in common with Crustacea than other insects have, and are supposed to be primitive. In general structure they are very similar to the larvae of the higher insects, but the various genera have characteristic features by which they can be identified.

The Bristle-tails[3] (the *Thysanura*) have ten abdominal segments, and the last of these bears long, backwardly projecting, antennae-like processes or *cerci.* The tiny, fragile, white *Campodea* is by some considered to be the most primitive of all

[1] Although this classification is adopted here, the order of the presentation of the orders has been left as in the 1st edition, since this seems to give a more desirable sequence for practical study.

[2] *Aptera* of the *Cambridge Natural History,* which see (vol. *Insects,* Pt. I.) for full details of the group.

[3] These forms are not described in this book; for details of their structure see *Cambridge Natural History,* vol. *Insects,* Pt. I. pp. 180-197.

insects. *Lepisma saccharina*, the Silver-fish, may be nearly ½ inch long, and is found in the meal or sugar which it nibbles.

The Spring-tails (the *Collembola*) have not more than six abdominal segments, the first of which bears a peculiar tube or papilla of undetermined function. Most of them possess two appendages attached to the 4th or 5th abdominal segment, which, in life and when at rest, are flexed under the body, but which by a sudden jerking movement cause the "spring" to which the popular name of these creatures owes its origin. *Podura aquatica* is a Spring-tail which lives on the surface of stagnant waters; *Anurida maritima* (*Lipura* of Lubbock) lives between tide marks on the shores of the English Channel.

Sub-class II.: EXOPTERYGOTA

Those which have wings when adult; but these wings appear as rudiments in an early larval stage and develop gradually, though there is a rapid growth and a marked change in form at the last moult. The metamorphosis from larva to adult is therefore in these cases termed "incomplete," for there is no pupal stage. This sub-class includes the following orders:—

Dermaptera	Earwigs.
Orthoptera	Cockroaches, Stick and Leaf Insects, Grasshoppers, and Crickets.
Plecoptera	Stone-flies.
Hemiptera	(*a*) *Heteroptera* (Bugs).
	(*b*) *Homoptera* (Cicads, Froghoppers, Aphids).
Ephemoptera	May-flies.
Odonata	Dragon-flies.

Sub-class III.: ENDOPTERYGOTA

Those with complete metamorphosis, in which wings first appear externally at the formation of the quiescent pupa, as in the following orders:—

Coleoptera	Beetles.
Neuroptera	(*a*) larvae with biting jaws, Alder-flies.
	(*b*) larvae with sucking mouth-parts, Lace-wing flies, Ant-lions.
Trichoptera	Caddis-flies
Lepidoptera	Butterflies and Moths.
Diptera	House-flies, Gnats, Crane-flies.
Hymenoptera	Ants, Bees, Wasps, Gall-flies, Saw-flies, Ichneumon-flies, etc.

CHAPTER XVI

INSECTA (*continued*)

Order: LEPIDOPTERA (BUTTERFLIES AND MOTHS)

General Characteristics. The Wings. THE *Lepidoptera*, or *Scale-winged Insects* (Gk. *lepis, lepidos*, a scale), are characterised, as their name infers, by the presence of scales which cover the surface of the two pairs of large membranous wings. These scales are very minute, and vary much in form and colour; to them is due the typical marking and beautiful colouring of different butterflies and moths (see Fig. 169).

The Proboscis. The mouth also of the Lepidopteran insect is characteristic. There is usually a long tubular proboscis, which, when not in use, is kept coiled up in a vertical spiral below the head (Fig. 161). This proboscis appears to be formed, not of the upper and lower lips (labrum and labium) as in Diptera (p. 368), but of the two soft jaws or maxillae, which are long and grooved and held together to form a tube. An exception to this is seen in the Wood Leopard Moth (*Zeuzera*), in which the maxillary lobes are always separate; they are absent altogether in the Goat Moth (*Cossus*). The other mouth-parts are small and inconspicuous, except for the sensory palps of the labium, which are large, and usually held curving upwards in front of the head (Fig. 161, *p*). The tubular proboscis is used in sucking up the nectar of flowers on which the insect feeds. In some cases its length

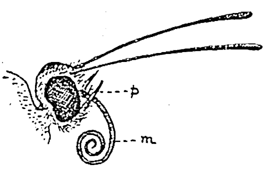

FIG. 161.—Head of the Large White Butterfly (*Pieris brassicae*) seen from the side. *p*, Labial palp; *m*, proboscis, partly uncoiled.

is remarkable when compared to the size of the insect. In certain Hawk-moths it is as much as 10 inches long. At the tip are minute spines, the function of which is uncertain; it is suggested that they may be sense-organs, or they may be instruments for piercing the nectaries of flowers.

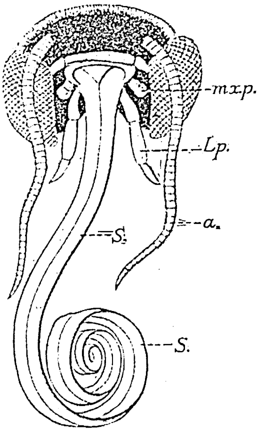

FIG. 162.—Head of a Moth, seen from in front.

S, Sucking tube or proboscis; *a*, antenna; *Lp*, labial palp; *mx.p*, maxillary palp.

The Head. The head bears, besides the proboscis, two large compound eyes, often a pair of simple eyes as well, and two long, many-jointed antennae—club-shaped and smooth in butterflies (see Fig. 163, *a*, *b*, and *c*), tapering to a point and often feathered in moths (see Fig. 163, *d*, *e*, *f*, and *g*).

Development. The metamorphosis is complete and very striking. The larva is known here as the *Caterpillar*, and it displays externally, even when full grown, no signs of the organs which appear in the imago, some of these first becoming apparent at the last change of skin immediately preceding the pupal stage. The *Pupa* is covered by a firm outer skin or shell, formed from a chitinous secretion which hardens its surface.

The Lepidoptera are conveniently divided into two large sub-orders—the Butterflies and the Moths.

Butterflies (Rhopalocera).[1]

In Butterflies the antennae are long and usually club-shaped, or are thickened just before the tip. In some of the latter cases, the actual tip turns over to form a little hook (Fig. 163, *c*). The antennae are not hairy, except occasionally at the base. The form of the antennae is one of the distinguishing marks between Butterflies and Moths, but the general appearance and habits of the two groups also differ; butterflies have slighter bodies and are more brightly coloured

[1] Gk. *rhopalon* a club; *keras*, a horn.

as a rule. They fly by day, and when at rest the wings are in most cases held vertically, though there are exceptions to this. The caterpillars of the two groups are alike in general structure, but those of butterflies pupate above ground. (Compare with Moths, p. 252.)

Type: **The Cabbage White Butterfly** (*Pieris brassicae*).

This is an excellent example to study in order to get a knowledge of the structure and habits of a typical Butterfly, for it is all too plentiful; also it is easy to feed, and it goes through its metamorphosis without any concealment. The different stages of its life-history are illustrated in Plate II.

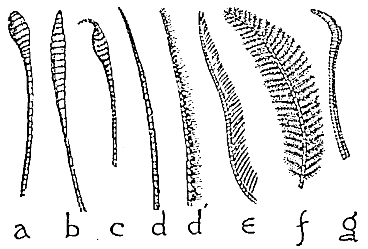

FIG. 163.—Antennae of Butterflies and Moths.

a, Large White Butterfly; *b*, Purple Emperor Butterfly; *c*, Large Skipper Butterfly; *d*, Buff Tip Moth, female; *d′*, Buff Tip Moth, male; *e*, Grass Eggar Moth; *f*, Emperor Moth; *g*, Burnet Moth.

The Eggs. There are two broods in the year. The eggs may be found in May, or again in July or August, when they are much more plentiful than earlier in the year. They are small, yellow, blunted, conical bodies, prettily ridged and ribbed. They are often to be found on the lower side of a cabbage leaf, or of a garden nasturtium leaf, in clusters of from six to a hundred. These eggs hatch in seven to ten days, and the little caterpillars usually make their first meal off their discarded egg-shells.

Fabre suggests that this queer meal is taken because of the immediate need of spinning silk as a foothold for the young caterpillar on the slippery cabbage leaf, the egg-shells providing the right nourishment to expedite the formation of silk in the silk glands.

Larva. The hairy little caterpillars at first keep more or less together, eating tiny holes in the blade of the leaf. When the first moult is imminent, they collect side by side and remain motionless for two days. Then they

discard their head coverings, push their body skins off backwards, and speedily begin to feed again, continuing to do so with little rest until once more a moult takes place. After the third moult, they separate and feed alone, moulting once or twice more before they are full grown. The skins they have thrown off may be often found in clusters on the leaves they have frequented. When full grown the caterpillar is about $1\frac{1}{2}$ inches long and $\frac{1}{4}$ of an inch broad; its colour is pale yellowish-green with three yellow longitudinal lines. The body is dotted all over with little raised tubercles that are black on the back, and brown on the sides and underneath the body.

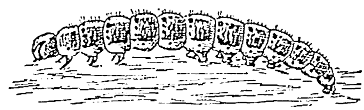

FIG. 164.—The Larva of *Pieris brassicae.*

From each tubercle arises a short, rather stiff hair. The body consists of a head and thirteen segments, the last of which, however, is hidden by the one before it, and so cannot be seen in a surface view (Fig. 164). The three thoracic segments behind the head bear, as in all caterpillars, three pairs of five-jointed legs, each ending in a little curved claw. On some of the abdominal segments are structures known as *cushion feet* or *pro-legs*. These are fleshy protuberances from the body, which are not jointed, though the very elastic skin covering them may be thrown into transverse wrinkles when the foot is retracted. Each such foot has, at its tip, a half-circle of little hooks by means of which the caterpillar can cling very firmly. On the last segment, the pro-legs are turned backwards, and are generally distinguished as the "claspers."

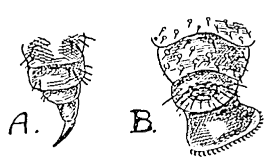

FIG. 165.—*Pieris brassicae.*

A, Thoracic five-jointed leg; *B*, pro-leg or "cushion foot" of abdomen.

Respiration.

Respiration takes place through spiracles, little openings on each side of the first thoracic and first eight abdominal segments. They appear as light-brown oval dots with a narrow dark rim round them; the actual aperture is not visible to the naked eye (see Fig. 164, where the spiracles appear as dark dots just above the legs in the segments mentioned above).

The Head of the Larva.

The *head* bears only rudimentary antennae and several pairs of small simple eyes, or ocelli. Caterpillars apparently have very dim sight, and even this is limited to the recognition of objects quite close to them. However, it suffices, no doubt, for their limited larval life, during which they rarely leave their food-plant, escaping the attentions of their enemies, not by their own activity, but by their secluded habits and protective coloration, and, in some cases, by their objectionable taste or hairiness.

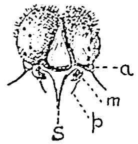

FIG. 166. — Head of the Caterpillar of *Pieris brassicae*, seen from in front. *a*, Antenna; *m*, mandible; *p*, maxillary palp; *s*, spinning-tube.

Since the caterpillar stage is that in which feeding is most active, we find that the mouth-parts are specially adapted for the rapid cutting of the leaves which form the food. The mandibles, which are absent in the imago, are here large and powerful, whilst the maxillae and labial palps, so greatly developed in the butterfly, are rudimentary in the caterpillar. The labium, or lower lip, bears a little tubular, projecting structure known as the *spinneret*, for into it opens a duct connected with a pair of silk glands, from which the larva can spin a fine white silken thread over the leaf on which it is feeding, so gaining a firm foothold on it.

Preparation or Pupation.

When full grown the caterpillar ceases to feed and becomes restless, leaving its food-plant and seeking to climb. It climbs even slippery surfaces, such as that of glass, with great ease, giving out from its spinneret the silk thread, which, by means of a side-to-side movement of its head as it climbs, it fixes to the surface as a zigzag silk ladder. It holds on to this with its abdominal feet whilst, with its head outstretched, it is adding to it above, rung by rung. (Such a "ladder" is shown in Plate II. below each chrysalis.) Having reached by this means a suitable spot, the caterpillar prepares to pupate. It first spins a little carpet of silk against the surface to which it clings, fastening its claspers into a thickening of silk at one side of this. Then it extends itself along the surface, usually so that it is in a vertical position with head uppermost, and, turning its head right back over its thorax, it spins a little girdle of silk across its body at the level of the second or

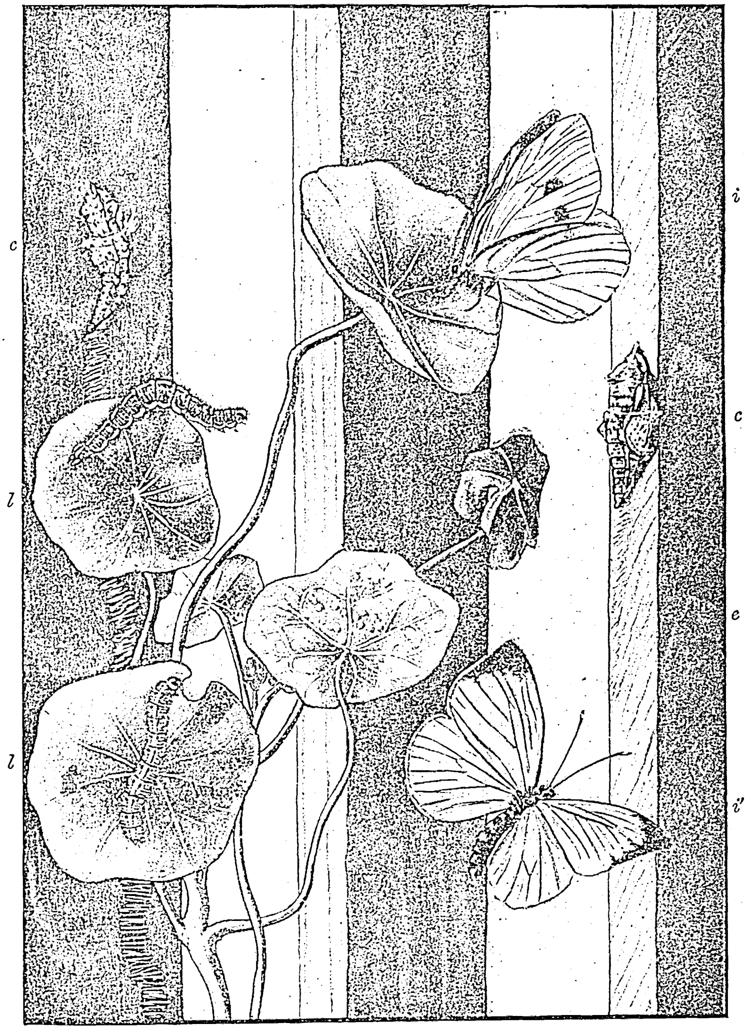

Plate II.—*Pieris brassicae* in different Stages of its Development.

e, Eggs below a nasturtium leaf; *l*, larvae; *c*, chrysalis; *i*, imago, male; *i'*, female.

third segments of the abdomen, fixing it to the surface on each side and repeating the action until the girdle is many strands thick. It then again stretches itself out, and its body shortens and swells, until, after about two days' quiescence, the skin splits and is pushed off at the hind end, whilst the body from within quickly swells up and takes on the pupal or chrysalid form.

The Pupa or Chrysalis. The rudiments of wings, legs, antennae, and compound eyes now appear, and for a moment the wings are free; quickly, however, a chitinous fluid exudes from the body and hardens all round the pupa, forming a delicate transparent "shell," which is yellowish-green, spangled with yellow and black dots, and beset with little sharp points and angles which prevent it slipping from its silken support. There is one specially large dorsal projection on the thorax, and also one on each side a little further back (Fig. 167, *d* and *l*). The silk thread lies between the dorsal and the lateral spines.

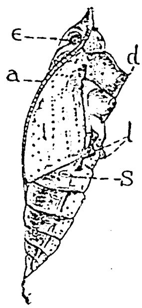

FIG. 167.—Chrysalis of *Pieris brassicae*. *c*, Compound eye; *a*, antenna; *s*, spiracle; *d*, dorsal spine; *l*, lateral spines.

A butterfly pupa is generally called a *chrysalis* because of the golden spots which in so many cases decorate it (Gr. *chrysos*, gold). The chrysalis can now only move its abdominal segments, jerking them laterally if touched. It remains otherwise entirely quiescent—for two or three weeks only, if it is the first brood of the year which pupated in June, or for the whole winter if it is the second brood which pupated in the autumn. The butterflies of this latter brood emerge in April or May, but so many of the chrysalids get destroyed by birds and other enemies during the winter, that the butterflies in the spring are not nearly so numerous as those that emerge in July and August.

Emergence of Imago. When the insect is about to emerge, the pupal skin splits along the back of the thorax, and the imago gradually pulls itself out. Its wings are at first damp and crumpled up, but in the air they gradually expand, dry, and stiffen, and then are strong enough to support the butterfly.

The Imago.

In the imago, the division into head, thorax, and abdomen is very distinct. The thorax of the butterfly is black and hairy, and bears three pairs of jointed legs and two pairs of wings. The upper surfaces of the wings are yellowish-white with certain black spots and smudges on them, which differ in male and female.

The male has the apex of each front wing either black or brown, and there is a dark stain at the base of each wing, and a dark smudge—partly hidden by the front wing—on the front margin of the hind wing; this is the only dark pigment on the upper side of the wing. The female has, in addition, two dark spots on her front wing with a dark smudge along the inner margin.[1] The pigment is generally darker in the summer butterflies than in those which emerge in May.

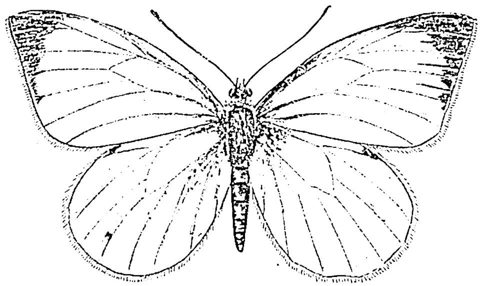

FIG. 168.—*Pieris brassicae* (male).

On the under side of their wings the two sexes are much more alike. In both there are two dark spots on the front wings, and their tips are yellow, whilst the hind wings are entirely yellow, and are covered with minute scattered black specks, with an inconspicuous black smudge at the centre of the front margin.

Wing Structure.

The *colouring of the wing* is due to pigment in (or, in the case of some other butterflies, to the striation of) many thousands of little scales, which cover its surface and come off on the finger as a fine dust, if the wing is gently rubbed. Under the microscope these scales are seen to vary considerably in form, size, and tint. They are modifications of hairs, and transitional stages may be seen (see Fig. 169). In their natural position on the wing they overlap in regular series like the tiles on a roof, each being fixed by a short stalk into a socket in the membrane of the wing.

[1] For terms used in describing the different parts of the wing see Fig. 170.

If the scales are gently brushed off, the characteristically few "veins" or "nervures" of the wings will be seen, running from the base of the wing to its outer margin; these branch so frequently that the veins are far more numerous at the margin than at the base. The *cross* nervures in the wings of butterflies are few or are entirely absent, and so there are very few areas closed on all sides by them. Such areas are called "cells," and in the Large White Butterfly there is only one "cell." In some butterflies, *e.g. Vanessa*, there is no "cell" at all in the wing.

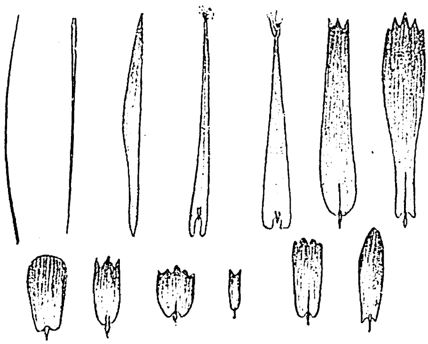

FIG. 169.—Scales rubbed from the wing of *Pieris brassicae*.

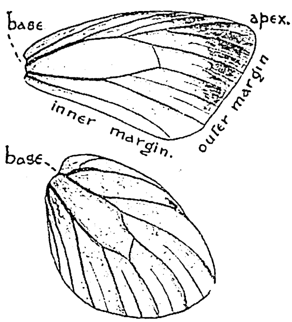

FIG. 170.—Anterior and posterior wing of *Pieris brassicae* with scales rubbed off to expose "nervures."

The *wing* itself is formed of two delicate membranes held apart by an irregular tissue. At intervals along definite lines these two membranes are more widely separated to allow of the passage of the veins or nervures shown in Fig. 170. The structure of the nervures does not seem to have been very fully investigated, but they always contain a chitinous supporting rod, and, in some cases, a trachea and blood-cells have been seen in them.[1]

The Abdomen.

In the abdomen nine segments seem to be represented in the female, and ten in the male, but in each case the last two are difficult to distinguish in the imago, as they are more or less with-

[1] *Cambridge Natural History*, vol. vi. p. 330.

drawn into the body. They are more clearly seen in the chrysalis.

There are six very distinct pairs of abdominal spiracles, and a seventh pair is said to exist. There is also a pair of spiracles on the first thoracic segment. No appendages at all are borne on this part of the body.

The Head. The *head* is shown in Fig. 161, and it and the characteristic proboscis are described on p. 238.

Food and Habits. The butterflies live an active aerial life, flitting with a zigzag motion from flower to flower, sucking nectar from them for food. They are the commonest butterflies seen on a sunny day in flower and vegetable gardens. The butterfly, if a female, should be carefully watched as she hovers over the flowers, for she may be about to lay her egg-clusters on the cabbage or nasturtium leaves.

The change from the crawling voracious caterpillar to the quiescent pupa, and then again to the active winged butterfly, is very striking, but it is much more gradual than appears externally. By dissection it has been shown that, in the caterpillar, even some time before pupation, the rudiments of the organs of the perfect insect have already been formed, but they are at that stage compressed within the body. At pupation they are suddenly pushed out, and so cause the marked change in shape at this time. A resting period is then necessary for the completion of the internal structure and of the new mouth-parts which have now to be fitted for sucking nectar from flowers. The biting mandibles of the caterpillar are no longer needed and disappear altogether. The change in diet is necessitated by the change in the mode of life; the active, flying butterfly needs a lighter and more nutritious diet than the slowly crawling caterpillar.

Economic Danger. The caterpillars of this butterfly are often very common and very destructive, especially the numerous summer brood, which feeds almost entirely on cabbage. The smaller spring brood is found on various food plants, chiefly those of the cruciferous order. The summer brood, however, is very liable to the attack of a four-winged hymenopterous insect known as the "ichneumon fly" (*Apanteles* (*Microgaster*) *glomeratus*). This insect lays its eggs inside the *eggs* of the Butterfly,[1] the same or different

[1] J. H. Fabre, *The Wonders of Instinct*; also *The Life of the Caterpillar*.

mother ichneumon flies piercing with a thread-like ovipositor each infected egg thirty or more times. Seventy-five parasites have been known to emerge from one unfortunate host. The larvae of the fly live parasitically on the juices of the caterpillar, until they are about to pupate, when they emerge one after the other through a little hole in the skin and pupate near it, surrounding themselves with yellow silk cocoons (Fig. 171, *B*). At this point the caterpillar usually dies, and much as we may dislike the methods of the ichneumon fly, it doubtless is of great use in preventing the Cabbage White Caterpillars from becoming a serious plague (cp. page 487).

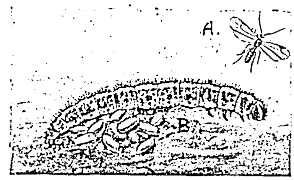

FIG. 171.—Caterpillar of *Pieris brassicae* attacked by the Ichneumon Fly.

B, Cocoons of larvae which have made their way out of the body of the caterpillar; *A*, one ichneumon fly which has emerged from one of the cocoons.

Pieridae.

Belonging to the same family of Butterflies as the Large and Small Cabbage Whites, *i.e.* the family of the Pieridae, are the Orange Tip and the Brimstone Butterflies. They all have the same habit of supporting the body, by a silken girdle, when pupating.

The **Orange Tip** spends nine or ten months of the year in the pupal stage. The butterfly emerges in May, and lays its eggs in June, on the flower-stalks of some cruciferous plant, frequently cuckoo-flower or hedge-mustard. On this plant the bluish-green caterpillar feeds, finally changing to a curiously shaped pupa such as is shown in Fig. 172.

FIG. 172.—Pupa of the Orange Tip Butterfly suspended on a stem of Cuckoo-flower.

The **Brimstone** attracts special notice, for it is usually the first butterfly to appear in the spring. It hibernates in sheltered copses during the winter, and a warm day, even in March, is sufficient to rouse it to activity. It lays its eggs under the leaves of the buckthorn, which form the food of the greenish caterpillar until July,

when it pupates. The perfect insect emerges at the end of July or beginning of August, and lives right on till the following spring, a period of seven or eight months, which is an unusually long life for a full-grown winged insect.

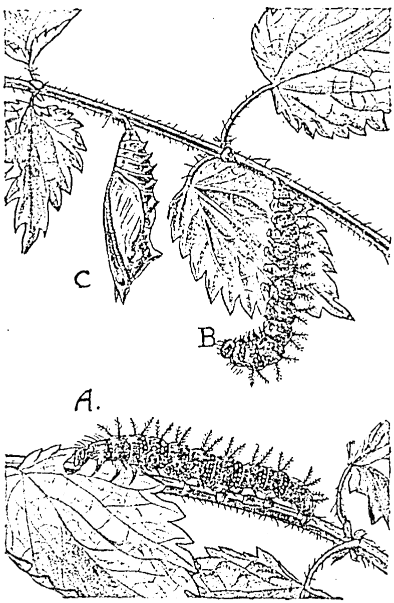

FIG. 173.—Stages in the life of the Peacock Butterfly (*Vanessa Io*).

A, Caterpillar feeding on nettle; *B*, caterpillar suspending itself when about to pupate; *C*, suspended chrysalis.

Nymphalidae. The predominant British family of butterflies is that of the Nymphalidae, of which the genus *Vanessa* (= *Pyrameis*) includes the Red Admiral (*V. atalanta*), the Painted Lady (*V. cardui*), the Peacock (*V. Io*), and the Tortoise-shells (*V. urticae* and *polychloros*), a gaily coloured group as the names of its members suggest. In all these butterflies, the front pair of legs is much reduced in size, and is usually smaller in the male than in the female. The caterpillars of them all are set with stiff hairs so that they have a bristly appearance; also all have the same habit of suspending themselves freely by the tail when about to pupate.[1] They are able to do this securely because of the little process covered with tiny hooks (known as the "cremaster") which is developed at the end of the pupa and which fixes into the little cushion of silk which the caterpillar makes before pupation.

The **Tortoise-shells** and **Peacock** live through the winter in the winged state, and may be again seen on the wing in

[1] For investigations into the stinging properties of these hairs, and some details of the act of pupation in *V. polychloros*, see *Life of the Caterpillar*, by J. H. Fabre, chap. viii.

April. Their caterpillars feed in companies, those of the large Tortoise-shells on elms or various other trees, the small Tortoise-shells and the Peacocks on nettles. The **Painted Lady** and **Red Admiral** are not known to hibernate, but the former frequently migrates here from N. Africa early in the summer, and the latter is suspected of similar immigration. The caterpillars of the Painted Lady feed usually on thistles, concealing themselves by doubling over the leaves and binding them together with silk thread. The Red Admiral caterpillars are common on nettles. They also bind a few leaves together to form a hiding-place, but they live singly, not in companies.

The **Fritillaries** (*Argynnis* and *Melitaea*) are distinguished by their fulvous (yellow-brown) wings, spotted and marked with black above, but with the hind wings usually showing on their under surface spots and bars of silvery white.

The caterpillars of *Argynnis* are usually found feeding on dog-violet leaves, but also sometimes on sweet violet or on pansy.

Lycaenidae. The family Lycaenidae includes the "Blues," Coppers," and "Hairstreaks," all easily recognised by their characteristic colouring, and also by the peculiar shape of the caterpillars, which are short, much thicker in the middle than at either end, and have no stiff or conspicuous hairs. In shape they are more like wood-lice than like ordinary caterpillars. The front legs of the butterflies are only slightly shorter than the other legs. The Hairstreaks are characterised by a little process on the hind margins of each of their back wings, known as the "tail," and also by the fine lines of white running across the under sides of the wing, from which they get their name of "Hairstreaks." They are high-flying butterflies and not easy to catch, except when they come down to visit the bramble flowers.

Some of the caterpillars of the Blues are said to eat Scale Insects and Aphides, whilst on the other hand a friendly relationship exists between the caterpillars of other species of *Lycaena* and certain species of ants. The ants are known to stroke the back end of the caterpillars, and thus induce them to give out a juice from a gland situated on the third segment from the end of the body; this juice is then eagerly licked up by the ants.

CHAPTER XV II

INSECTA (*continued*)

Order: LEPIDOPTERA (*continued*)

Moths (Heterocera).

General Characteristics. THAT group of the Lepidoptera to which moths belong is a very large and a rather heterogeneous one, but all its members are usually to be known by the form of the antennae, which are thickest in the middle and pointed at the tip. Often also they are set with fine hairs, when they are said to be "feathered" or pectinate (Fig. 163, *e*, *f*). Most moths have thicker, heavier bodies, and wings with duller colouring, than butterflies. They usually fly at night and pupate in the earth, or occasionally in the air, in which case they surround themselves with a cocoon—an extra wrapping of silk threads sometimes intermixed with hairs or earth. When at rest, a moth usually holds its wings horizontally over its back instead of vertically as is the habit of butterflies. In some few moths there is no proboscis, the maxillary lobes hanging freely from the mouth, *e.g.* in the Wood Leopard (*Zeuzera pyrina*).

The Silkworm Moth Bombycidae). Perhaps the moth whose life-history is most frequently watched and is best known, even in this country where it is not a native, is the **Silkworm Moth** (*Bombyx mori*), which feeds on the leaves of the mulberry tree, or, if these are not to be had, on lettuce. This moth has been widely cultivated in many lands for so many ages, because of the valuable silk the larva spins, that its real native country is not certainly known, but it seems probable that it came originally from China. It is related that in 2600 B.C.,[1] Si-ling-chi, the wife of the emperor of

[1] *L'Histoire générale de la Chine*, by M. Mailla.

China, Hoang-ti, first discovered how the silk could be wound off the cocoon, and further how this silk could be woven into fabrics, and so she introduced into her country this industry which made it rich and famous. From China the industry spread gradually all over the world. There is no other insect which has for so long played, and still plays, such an important part in human life, giving work to very many thousands of people, and making possible the production of most delicate and beautiful fabrics.

The details of the life-history of the Mulberry Silkworm Moth are so well known that they will not be repeated here. Some members of the family Saturniidae are now also cultivated for their silk. *Antherea paphia* is the Tussore Silk Moth of India.

The Buff Tip Moth (Notodontidae). A good typical British moth to study is the Buff Tip Moth (*Phalera bucephala*), which is very common in London and in the south of England generally—indeed it occurs throughout Britain. The whitish eggs of the moth are laid, usually in July, in clusters on the under side of the leaves of many different trees. Round London, lime, elm, and hazel are perhaps those most frequently chosen. Early in August, the groups of tiny yellow and black caterpillars may be found, all still on the same leaf where they began life, feeding voraciously side by side (Fig. 175, *A*). After a time they cease feeding and rest for three days, then they shed their skins and begin once more to feed.

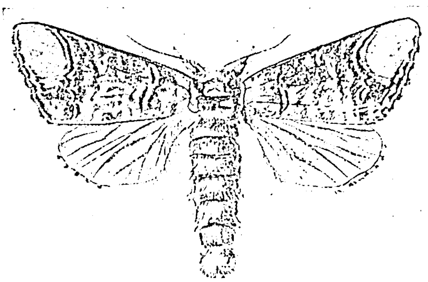

FIG. 174.—Imago of the Buff Tip Moth.

Before the moult, the head is black and relatively small, but afterwards it is disproportionately larger and at first yellow, though it gradually darkens. The body also is more hairy after the moult than before it.

In four or five weeks, during which time several moults will have occurred, the larvae will be full grown, and will

probably have stripped of its leaves the twig on which they have been feeding. They are big, fat caterpillars nearly two inches long. Their bodies are yellow with interrupted black stripes running longitudinally down them (see Fig. 175, *B*). They now cease feeding and travel down to the earth, in

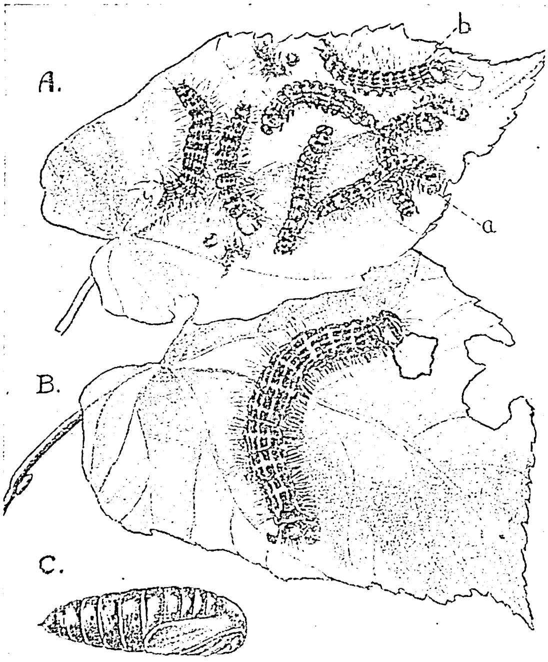

FIG. 175.—Stages in Life of the Buff Tip Moth.

A, Lime leaf with young larvae, several of which have just shed their skin; *a*, caterpillar just before the moult; *b*, caterpillar just after moult, with bigger head. *B*, Older larva now feeding alone. *C*, Pupa.

which they pupate. It is at this stage that we find the caterpillars so frequently on the path below the limes and elms, and if they are carried home the change to the pupa can very soon be seen. The caterpillars enter the damp earth, their bodies shorten, and they become dull-looking and apparently lifeless; but if left for a time in the earth, they will be found to have cast off their larval skin, and to have

become compact, reddish-brown pupae as shown in Fig. 175, *C*. The rudimentary mouth-parts, antennae, and wings of the moth are now distinctly visible through the semi-transparent shell of the pupa, and the spiracles can also be seen on the segmented abdomen. In this quiescent state, only moving the abdomen very slightly if disturbed, the pupa remains all the winter, the moth not emerging until June or July. It is not often seen, for it flies chiefly at night, and when at rest its beautifully marked brown and fawn wings, folded over its body, make it difficult to distinguish from the bark of the tree on which it settles (Fig. 174).

Belonging to this same family is the strange **Puss Moth**, the green and purple-brown caterpillar of which is well known because of the grotesque attitudes into which it contorts itself when disturbed, and also because of the two strange whip-like processes at the end of the body. These are the two claspers modified into two long tubes, which are held sloping upwards; and from these can be protruded two fine pink threads which may be thrust rapidly out, curving over the back, or drawn in. It feeds on poplar, sallow, or willow. When full grown it pupates within a very hard woody cocoon which has one thinner end. When the moth is ready to emerge, the chrysalis cuts through this with a special keel-like structure which it has on its front end, and further the cocoon is softened by a special secretion so that the moth can extricate itself. The pupal stage may last nine or ten months.

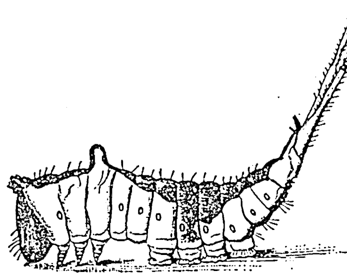

FIG. 176.—Caterpillar of the Puss Moth (*Dicranura vinula*).

The "Poplar kitten" and "Alder kitten" are caterpillars with similar tail appendages.

Hawk Moths (Sphingidae). A family of moths well represented in Britain is that of the Hawk Moths (Sphingidae); it is a family specially easy and interesting to study, because of the size and the beauty of both caterpillars and perfect insects. The caterpillars are usually smooth-skinned,

and are peculiar in having a projecting horn on the eighth abdominal segment. In most of them, also, the sides are marked with seven oblique coloured stripes. In the **Privet Hawk** (Fig. 177), the caterpillar when full grown is three inches long, and is green with oblique white and purple stripes. Behind the horned segment two other reduced segments are visible, the last bearing a large pair of claspers. The general structure of the caterpillar is similar to that of the Large White Butterfly described in Chapter XVI. All the Hawk Moth caterpillars, when full fed, bury themselves in the ground, and there change to naked pupae, remaining in that stage all the winter. In some, the proboscis of the enclosed moth projects from the pupa like a handle. The moths themselves are very thick-bodied, and have rather long,

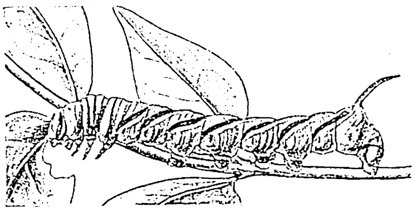

FIG. 177.—Caterpillar of the Privet Hawk (*Sphinx ligustre*) feeding on Privet.

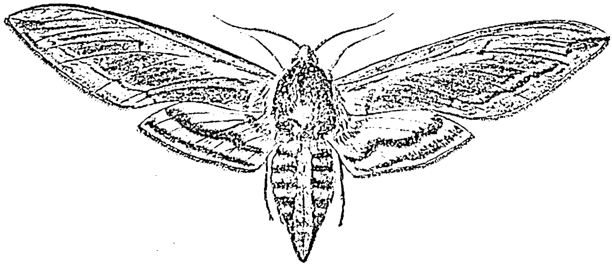

FIG. 178.—The Privet Hawk Moth. ($\frac{3}{4}$ nat. size.)

narrow wings; the thick antennae are pointed at the tips (Fig. 178). Many of them are beautifully marked, and are coloured pink and green, brown, fawn, russet, and yellow.

Burnet Moths (Zygaenidae). Burnet Moths are also very common, especially the **Six-spot Burnet** (*Zygaena filipendulae*). Here the yellow, black-spotted caterpillar, which feeds on clover, bird's-foot trefoil, and other plants growing

amongst the grass, ascends a grass stem when about to pupate—generally in June—attaches itself to the stem, and surrounds itself with a spindle-shaped cocoon which is yellow and glazed (Fig. 179, *b*). Within this outer case the pupa forms. When the moth is ready to come out, the pupa, which is capable of more movement than is usual at this stage, forces itself half out of the cocoon (see Fig. 179, *c*), and then from it there emerges the beautiful little moth. It has bluish-green front wings, each marked with six bright red spots, and its hind wings are almost entirely red except for a narrow green border. It is a day-flying moth, and has much brighter colouring than is found in the night-loving forms.

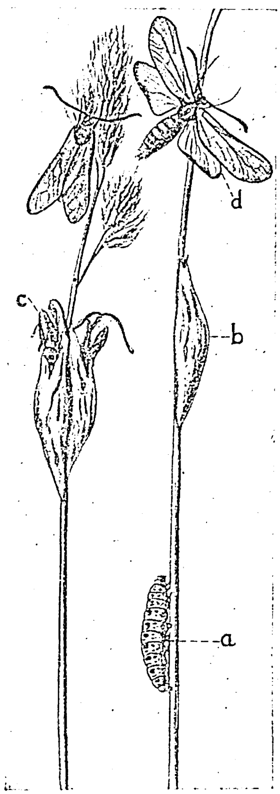

Fig. 179.—The Six-spot Burnet Moth (*Zygaena filipendulae*). *a*, Caterpillar; *b*, cocoon containing pupa; *c*, empty pupal skin projecting from the cocoon; *d*, moth which has emerged from *c*.

Tiger Moths and Ermine Moths (Arctiidae). Some members of the family Arctiidae are amongst the commonest and best known of the moths, as for example the garden Tiger Moth (*Arctia caia*), which in its caterpillar stage is known as the "woolly bear." This caterpillar is found on many different garden plants; it is covered with long, brown, backwardly sloping hairs. When about to pupate, it cuts off these with its jaws, and weaves them into a cocoon, which it makes amongst the foliage and within which it pupates. The moth, which emerges in July, is very brightly coloured, the front wings being buff with dark-brown markings and the hind wings a brick-red with black spots. In spite of such bright colouring, usually characteristic of sun-loving forms, this moth only flies at night, and therefore is not often seen.

The Buff Ermine (*Spilosoma lubricipeda*) is also common in gardens, its yellow, grey, or brown caterpillar having a lighter stripe and bushy tufts of hairs down each side. As in the "Tiger," the hairs are used to strengthen the cocoon, which is spun amongst the leaves and in which the winter pupal stage is passed. In June, the yellowish-white, dark-spotted moth emerges.

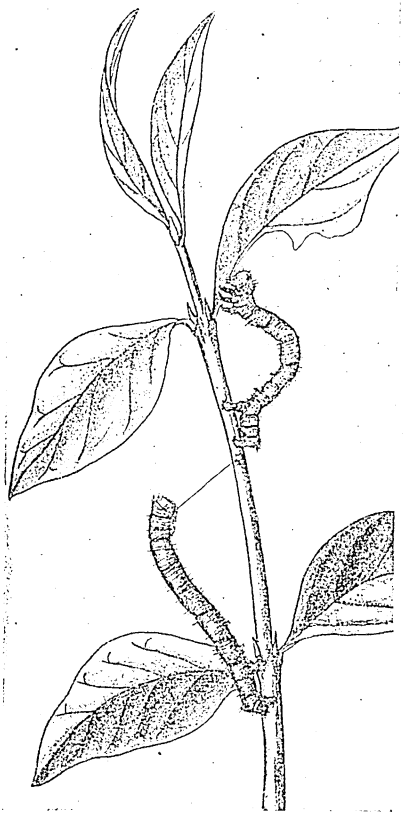

FIG. 180.—A "Looper" Caterpillar feeding on Privet. (Natural size.)
The lower specimen is resting, supported by a fine silk thread attaching its head to the twig.

The Cinnabars have conspicuous caterpillars with alternate bands of orange-yellow and purplish-black on them; they feed on ragwort.

The Footman Moths are also nearly related; they feed on lichens. When at rest with wings folded they have a peculiar, stiff appearance, which, it is suggested, is the reason for their English name.

Goat Moths (Cossidae).

The Goat Moths are notable because of the habit which obtains amongst their very large reddish caterpillars of boring into and feeding on the wood of willow and other trees. They live thus in the trunk of the tree for three years, and their presence can often be detected by the goaty smell of the liquid which they excrete. When full grown, and nearly three inches long, the caterpillar

sometimes leaves the tree, and may be seen whilst it is searching for a convenient spot in which to pupate; this then takes place near some decaying log, for it makes for itself a rather flimsy cocoon of silk mixed with fragments of wood; more usually it pupates within the tree near the mouth of the tunnel. The moth emerges in June or July, a month after pupation. It is large and heavy, with a brownish body and greyish wings.

Wood Leopard Moths (*Zeuzera pyrina*) are closely related to the Goat Moth and have similar habits. These moths are fairly often to be seen round London in the summer, and are easily recognisable from the many dark spots which decorate the greyish-white surface of the wings.

The Looper Moths (Geometridae). **The Looper Moths** fly at night, and therefore are not very well known except to those who specially collect them. The caterpillars, however, from their special characteristics, are easily recognised. They have slender, generally brown or green bodies, and are peculiar in having only one pair of abdominal feet, in addition to the claspers, the pair on the ninth segment of the body. In consequence of this, they move with the curious looping motion which has suggested the name of the family (see Fig. 180). These caterpillars all readily spin delicate silk threads, with which, if disturbed, they quickly suspend themselves from the tree or plant on which they are living, climbing the thread back to their former position when the danger is past.

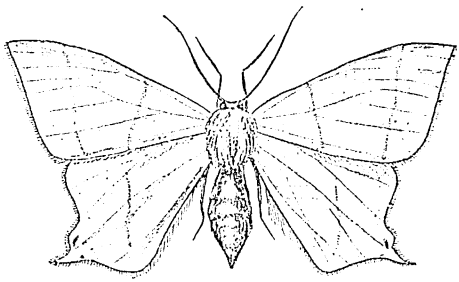

FIG. 181.—The Swallow-tailed Moth (*Ourapteryx sambucaria*).

(Drawn from a dead specimen. Natural size.)

The Swallow-tailed Moth (*Ourapteryx sambucaria*) is a common, large example of the Geometridae. The eggs are laid in July, usually on ivy leaves, and the caterpillars so strongly resemble little pieces of stick that it is quite difficult to detect them amongst the ivy twigs. They hold to the twig

by their abdominal feet only, the rest of the body being held stiffly out at an angle to the twig, so that it looks like a side branch. The caterpillars feed on ivy, hawthorn, or other plants, from August of one year until the following June, when they pupate. The moth emerges in July. It is a large yellowish form, with two thin darker marks across the front wings, and a distinct "tail" on the outer margin of each hind wing, with a small dark speck on it (Fig. 181).

The Magpie Moth (*Abraxas grossulariata*) is another very common Geometrid. It is the caterpillar of this moth which often destroys the foliage of currant and gooseberry bushes. Both caterpillar, pupa, and moth have a varied coloration of yellow, white, and black—a "warning" coloration, for this caterpillar is distasteful to birds.[1] It is, however, attacked by the *Tachina* fly, which lays its eggs on the caterpillar; its maggots become parasitic in the caterpillar, and finally kill it.[2] The pupae are to be found attached to the bushes by a few silk threads.

The Early Thorn Moth (*Silenia bilunaria*) has reddish-brown caterpillars, to be found in September feeding on hawthorn, birch, etc.; they are specially interesting because of their striking resemblance to a little rough twig. They pupate about the end of the month, and the moth, which also shows beautiful protective colouring, emerges in the early spring.

The China Mark Moths (Hydrocampidae). The China Mark Moths are worthy of mention because of the adaptation of the larvae to aquatic life, which is rare amongst Lepidoptera. The caterpillars live on the surface of the water, and surround themselves with cases made of leaves in the fashion of some caddis worms. Fig. 182 represents the **Small China Mark** (*Cataclysta lemnata*), the caterpillar of which makes for itself a case of duckweed bound together with silk. The eggs of this moth are frequently to be found on the under surface of the leaves of frogbit or of duckweed. The larva is said to be wetted at first by the water and to breathe through its skin, but later the spiracles become functional; when this has happened, it is found that the body, under water, looks silvery owing to the air surrounding it, and the case now becomes impermeable to water. The larva hibernates through the winter and pupates in May, creeping out

[1] *Colours of Animals*, E. B. Poulton (1890).
[2] *Insect Biographies*, J. J. Ward.

of the water on some plant stem, to which it fixes its case, and then spinning a little silken cocoon, within which it changes to the pupa (Fig. 182, *c*).

The moths are inconspicuous, whitish-grey forms, with a little darker marking on the wings. When folded, the hinder margins of the wings appear pleated, and the scales of the wing overlap each hind margin as a little fringe (Fig. 182, *d*).

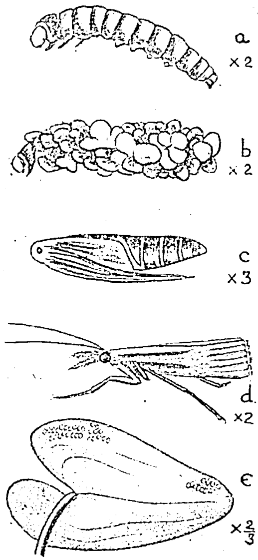

FIG. 182.—Stages in the Life of the Small China Mark Moth.

e, Eggs under a leaf of frogbit; *a*, caterpillar removed from its case; *b*, caterpillar in its duck-weed case; *c*, pupa; *d*, imago.

The Brown China Mark (*Hydrocampa nympheata*), in its larval stage, makes a much neater protective case by biting a little oval-shaped piece out of a large leaf, and then cutting out another piece of the same size, and binding the two together with silk to form a little hollow, lens-shaped covering over the body.

Tussock Moths (Lymantriidae or Liparidae).

The Tussock Moths are rather small, dull-coloured forms, the males of which have conspicuously pectinate (comb-like) antennae (see Fig. 183, *M*). The females are often wingless, and the larvae usually have noticeable tufts or tussocks of hair on them. These hairs tend to come out when the caterpillar is handled, and to cause irritation and sometimes a troublesome rash on the skin.

The Vapourer Moth (*Orgyia antiqua*) is one of these "Tussocks." The caterpillar (Fig. 183, *L*) is of a pretty violet-grey colour with a light-coloured line down its back, spotted with red; it has four tufts of yellowish hairs rising up from the first four abdominal segments, as well as clusters of other, finer, softer hairs. The sides of the body are yellow.

These caterpillars are much more active than those of most Lepidoptera. They can quickly make their way over

the ground from one plant or tree to another, and they can feed on many different kinds of leaves. The caterpillars, therefore—which are hatched from one batch of from one to two hundred eggs—quickly scatter and so disperse the species, a process often left to the females of other moths, who fly from plant to plant laying eggs in scattered spots. It is interesting to note that here, where there is no need for the female to be active for this purpose, she is practically wingless (see Fig. 183, *F*), and never moves far from the cocoon from which she emerges. Her mate finds her there, for he is winged and can seek her. Her eggs are laid in one batch upon or near the cocoon. Neither male nor female Vapourer Moth is capable of feeding, for the proboscis is rudimentary. Since it is not necessary for them to fly far and wide, it is not necessary either for them to feed. The brown-coloured males fly with a curious looping course, which used to be called "vapouring," and hence their name. They are very common round London, flying in the day-time.

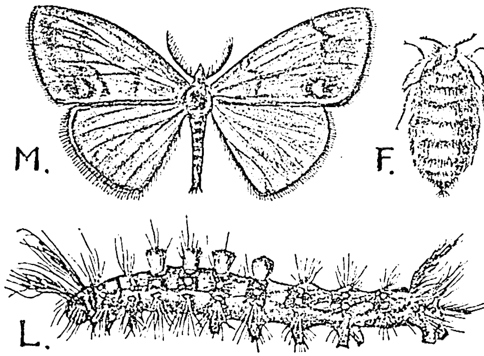

FIG. 183.—The Common Vapourer Moth (*Orgyia antiqua*). (Slightly enlarged.) *L*, Larva; *M*, male moth; *F*, female moth.

The Pale Tussock (*Dasychira pudibunda*) has both the male and female forms winged. The caterpillar used to be known as the "hop-dog"; it is not, however, often found on hops nowadays, but is frequent on birch, hazel, oak, and other trees. It is greenish or yellowish in colour, with a row of stiff tussocks of hair along its back; these are yellow on segments four to seven, with a longer, red tuft on segment eleven.

The Leaf-rolling Moths (Tortricidae).

The Tortrix Moths are very small, dull-coloured forms, the front wings usually with characteristic markings in each species, the hind wings greyish and without markings. Their

larval habits are peculiar. Many of them live protected by the leaves on which they feed, rolling them up in various ways and binding them with silk.

The Green Tortrix (*T. viridana*), which comes out in May, is very common. The caterpillar is green, with black warts on it, each wart bearing a hair. It is very commonly found on oaks, dropping by a thread from the boughs if shaken, and it often does a great deal of damage. The pupal stage is passed through protected by the rolled leaf. The moth which emerges (Fig. 184) has greenish front wings with a white fringe, and pale-brown hind wings with a grey fringe. The under side of all four wings is a silvery white. When at rest, the wings are held sloping obliquely to each other like a roof.

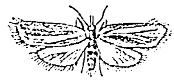

FIG. 184.—The Green Tortrix Moth. (Natural size.)

The larvae of other members of the family live inside seeds, fruits, or buds. One is the cause of the destruction of many of our peas, the caterpillars eating their way into the pods and destroying their contents. They pupate in the soil for the winter, and should then be carefully destroyed by deep hoeing and digging.

Clothes Moths. Leaf-Miners. Small Ermines. (Tineidae.) The Tineidae include the smallest of all the moths and some of the most destructive. To this family belong the little brown moths that lay their eggs on woollen materials and furs, the larvae of which work at times such havoc in our clothes by actually eating away the stuff. There is the **White-tipped Clothes Moth** (*Trichophaga tapetzella*), whose larva spins webs in which to conceal itself; whilst the larvae of the **Woollen Moths** (*Tinea pellionella* and *Tinea biselliella*) make for themselves little cases of particles of the material on which they are living, thus rendering their detection difficult (Fig. 185). When full grown, the larva creeps away into a corner, and pupates inside its case, the moth emerging in about three weeks. The first moths of the year appear as

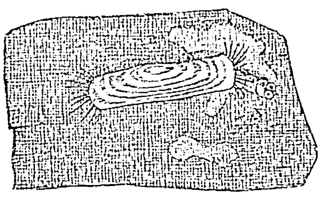

FIG. 185.—The Woollen Moth. (After Réaumur.)

The larva, covered by the case it has made eating a piece of cloth.

early as February, and several successive broods are reared before the winter. Naphthalene will drive them away from any material, or clothes may be protected merely by wrapping them in a paper bag with mouth securely closed, as, if no crack is left, the moths are unable to enter or to pierce the paper in order to lay their eggs in the material.

The Leaf-Miners burrow into a leaf, living inside it protected by the upper and lower epidermis of the leaf. The increase in size of the burrow as the larva itself grows can usually be traced. Leaves marked in this way (Fig. 186) are very common, and usually the markings are due to these small Tineids, though they are sometimes caused by certain small beetles and flies. The larva finally makes its way out of the leaf, usually in autumn, and pupates in a little cocoon close by (Fig. 186, *B*). From this there emerges in time the minute moth, which, in the species figured, has a yellowish-red head, bronze-coloured front wings, and narrow fawn hind wings; both pairs of wings are covered with long hairs (see Fig. 186, *C*).

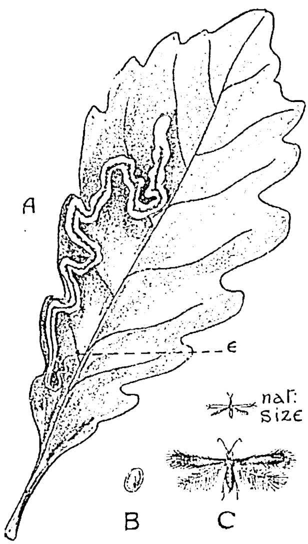

FIG. 186.

A, The serpentine mine of the Oak Miner larva (*Nepticula ruficapitella*); *e*, the point at which the burrow begins; *B*, cocoon; *C*, the Oak Miner Moth.

The Small Ermines (*Hyponomeuta*) are little moths with silky white fore wings speckled with black dots, and greyish hind wings. The caterpillars live in large companies protected by a common web, and different species are to be found on many different plants, especially on the apple, hawthorn, and bird-cherry. They will often strip a small bush of its foliage, and leave it covered with tangled webs, inside of which, in July, may be seen packets of whitish cocoons enclosing the yellow pupae.

Cutworms or Surface Caterpillars (Noctuidae). This name is given to the caterpillars of three different moths, the large **Yellow Underwing**, the **Turnip Moth**, and the **Heart and Dart Moth**. The first two moths are rather alike when at rest, as the upper wings of each are mottled brown and grey, but the back wings are distinctive, being yellow with brown marginal stripes in the former and of a brownish white colour in the latter.

The Heart and Dart Moth is rather like the Turnip Moth, but has characteristic heart-shaped and club-shaped brown markings on the front wings.

The caterpillars of all three are more or less soil-coloured, and are very destructive to plants, for they feed through the summer and autumn on plants near the ground, often cutting off whole young shoots. In the winter they take refuge in the soil, hibernating in little earthen cells, and wake in the spring with most voracious appetites.

Two other members of the family are also troublesome pests when young—the **Cabbage Moth**, which in the larval state infests cabbage, lettuce, and dahlias, and the **Dot Moth**, which attacks also fruit bushes and trees.

The caterpillars of the Cabbage Moth vary in colour a good deal; they are dull brown or green, with yellow or greenish lines and dots on them.

The Dot Caterpillar is more destructive; it is pale green or pale brown, with darker green or darker brown V-shaped markings; also it has a little horn at the end of the body.

Lackeys and Eggers (Lasiocampidae). The **Lackey Moth** itself is not very conspicuous, for it is all yellow or brown and flies at night in midsummer, but the little bracelet of eggs which it lays round the twig of a fruit tree or some forest trees is well known, for this remains exposed all the winter, the eggs only hatching in April. The caterpillars remain together most of their lives, constructing an irregular silken tent under which they can shelter. They are a slaty-blue colour, striped longitudinally with a central white line, on either side of which there are various black, orange-red and blue lines, with two conspicuous black spots on the head and segment next behind the head. These larvae often do serious damage to plum and apple trees; they pupate in June or July, spinning an oval silky cocoon with loosely woven outer

layers in which is entangled a sulphur-like powder; this powder is ejected by the caterpillar before pupation in the form of a fluid which scatters and dries in the air.

To this same family, *Lasiocampidae*, belong the Eggers, the Fox Moths, and the Drinker Moths—all large yellow-brown forms with hairy caterpillars that hibernate.

The Oak Egger caterpillar is easily recognised by the velvety black rings dividing the brown hairy segments and by its hard, light-brown, oval cocoon, the egg-like appearance of which probably suggested the popular name of the genus.

The Fox Moth caterpillar, when full grown in autumn, is all velvety black with a covering of short tawny and longer brown hairs dorsally and whitish hairs laterally.

The Drinker caterpillar gets its name from its love of sipping a drop of dew. It is slaty-grey with two lines of yellowish dots on the back; it is covered with black and brown hairs dorsally, but has tufts of shaggy white hairs laterally and a conspicuous, erect tuft of brown hairs on the second and on the eleventh segments.

These last three caterpillars are quite harmless, as they do not attack fruit trees, but live on heather, grasses, and other wild plants. Their hairs, however, are irritating to the human skin.

It has only been possible to mention here a few representative butterflies and moths, but it is hoped that those chosen for description or mention give a good idea of the variety of habits and forms amongst this very large and important order of insects, one which appeals to us not only on account of the great beauty of very many of its members and the interest of their varied individual life-histories, but also from the economic point of view. Mention has already been made of the importance to man of the activities of the silkworm. Then again the essential cross-pollination of many of our flowers is due to the butterflies or moths which visit them, and without this external aid certain species of flowers might become extinct. On the other hand, we need to know and to guard against the ravages of those forms which in the early larval stages destroy many of our edible or ornamental plants and also our clothes.

Classification of the Lepidoptera mentioned in Chapters XVI. and XVII.

Sub-order I. **Rhopalocera** (Butterflies).

Family 1. Pieridae.

The Large Cabbage White (*Pieris brassicae*).
The Small Cabbage White (*Pieris rapae*).
The Orange Tip (*Euchloë cardamines*).
The Brimstone (*Gonepteryx rhamni*).

Family 2. Nymphalidae.

Red Admiral (*Vanessa atalanta*).
Painted Lady (*Vanessa cardui*).
Peacock (*Vanessa Io*).
Large Tortoise-shell (*Vanessa polychloros*).
Small Tortoise-shell (*Vanessa urticae*).
Fritillaries (*Argynnis* and *Melitaea*).

Family 3. Lycaenidae.

The Common Blue (*Lycaena icarus*).
The Chalk Hill Blue (*Lycaena corydon*).
The Small Copper (*Chrysophanus phloeas*).
The Purple Hairstreak (*Zephyrus quercus*).

Sub-order II. **Heterocera** (Moths).

Family 1. Bombycidae.

The Silkworm Moth (*Bombyx mori*).

Family 2. Notodontidae. The Prominents.

The Buff Tip Moth (*Phalera bucephala*).
The Puss Moth (*Dicranura vinula*).

Family 3. Sphingidae. The Hawk Moths.

The Privet Hawk (*Sphinx ligustre*).

Family 4. Zygaenidae. The Burnets.

The Six-spot Burnet (*Zygaena filipendulae*).

Family 5. Arctiidae.

The Tiger Moth (*Arctia caia*).
The Buff Ermine (*Spilosoma lubricipeda*).
The Common Footman (*Lethosia lurideola*).
The Cinnabar (*Hipocrita jacobaeae*).

Family 6. Cossidae.

The Goat Moth (*Cossus ligniperda*).
The Wood Leopard (*Zeuzera pyrina*).

Family 7. Geometridae. The Looper Moths.

The Swallow-tailed Moth (*Ourapteryx sambucaria*).
The Magpie Moth (*Abraxas grossularia*).
The Early Thorn (*Silenia bilunaria*).

Family 8. Hydrocampidae. The China Mark Moths.
The Small China Mark Moth (*Cataclysta lemnata*).
The Brown China Mark Moth (*Hydrocampa nympheata*).

Family 9. Lymantriidae or Liparidae. The Tussock Moths.
The Vapourer Moth (*Orgyia antiqua*).
The Pale Tussock (*Dasychira pudibunda*).

Family 10. Tortricidae. The Leaf-rolling Moths.
The Green Tortrix (*Tortrix viridana*).

Family 11. Tineidae.
The White-tipped Clothes Moth (*Trichophaga tapetzella*).
The Woollen Moths (*Tinea pellionella* and *T. biselliella*).
The Oak Miner (*Nepticula ruficapitella*).
The Small Ermine (*Hyponomeuta padella*).

Family 12. Noctuidae.
Large Yellow Underwing (*Triphoena pronuba*).
Turnip Moth (*Agrotis segetum*).
Heart and Dart Moth (*Agrotis exclamationis*).
Cabbage Moth (*Mamestra brassicae*).
Dot Moth (*Mamestra persicariae*).

Family 13. Lasiocampidae.
The Lackey Moth (*Malacosoma neustria*).
The Oak Egger (*Lasiocampa quercus*).
The Fox Moth (*Macrothylacia rubi*).
The Drinker (*Cosmotriche potatoria*).

Practical Notes on Lepidoptera.

Study of the Cabbage White Butterfly.

1. In May or in July, watch the Large White Butterfly when she visits the cabbage bed or the garden nasturtium, and afterwards hunt for the eggs she may have left behind her. When found, mark the leaf on which they are, and visit daily. Keep a record of their development, noting dates of hatching, first moult, successive moults, time of dispersal of the brood, date of pupation, etc.

2. Bring a few large caterpillars indoors for more detailed study. Examine with a lens, and carefully sketch one of them, making clear all the main points in its external structure. Watch the movements of the jaws as the caterpillar feeds.

3. Place a full-fed caterpillar inside a tall glass cylinder.[1] Make the cylinder firm by fixing its lower end in a pot of earth, and cover the top with a piece of muslin or perforated zinc (Fig. 187). The caterpillar will probably begin at once to climb up the glass, and, when so doing, its structure can be very clearly seen, and also the way in which it secretes silk from the spinning-tube, fixing a zigzag ladder to the glass. When it reaches the top, it will probably stop and, after a time, fix itself in preparation for pupation. Note the time and method of fixing, watch the formation of the silken girdle which supports the body, and in two days' time be on the look-out for the splitting of the skin and the appearance of the chrysalis.

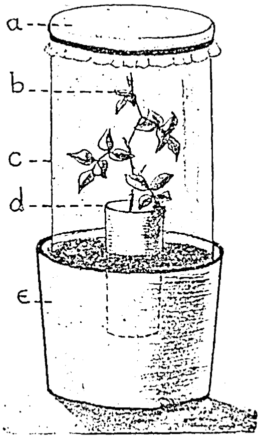

FIG. 187.—Simple Breeding-cage for the caterpillars of moths or butterflies.

e, A pot of earth; *c*, a glass cylinder; *d*, a pot of wet sand sunk in the earth, and containing the food-plant, *b*; *a*, muslin cover.

4. Try the effect of changing the environment of caterpillars when about to pupate. Cover the wall of the breeding cage in one case with gold paper, in another with black or red paper, and note the colour of the chrysalis in each case. Compare results with those given in *Colours of Animals*, by E. B. Poulton.

5. Put the chrysalis into an airy place, and when the time comes (*i.e.* in two or three weeks if it is the first brood of the year, or the following May if it is the second brood) watch for the emergence of the imago.

6. Distinguish the male and female butterflies, and draw a specimen of each. Suspend in the insect cage a small sponge soaked in honey and watch the butterflies feeding on it. Finally set the butterflies free, unless you are afraid of the possible damage their offspring may do to your cabbages or those of your neighbour!

Study of other Butterflies and Moths.

1. Collect any Lepidopteran eggs or caterpillars that you can

[1] The glass cylinders sold as candle screens are very suitable. Cheaper substitutes can be made by taking a 3-lb. glass jam jar and cracking off its base by running the top of a red hot steel knitting needle evenly round it.

find,[1] always bringing home with them a good supply of the plant on which you find them, as that may be the only one on which the larvae will feed.

Very small caterpillars may be conveniently kept at first in the glass-topped, round, tin breeding-boxes which can be bought at most dealers; larger caterpillars may be kept in such a simple breeding-frame as that shown in Fig. 187, made of a glass candle-shade and a pot of earth, the stalk of the food-plant being put into a small pot of wet sand to keep it fresh; the food itself must always be dry. Each kind of caterpillar should have its own home. This type of insect-cage is convenient when it is not known whether the caterpillar is that of a moth or of a butterfly, for in the former case, at pupation, it can enter the earth in the pot; in the latter case it will climb and pupate at the top of the cylinder. Many other varieties of insect-cage can be easily made, but it is important in them all to remember to arrange for an earthy floor, a means of keeping the food-plant fresh, good ventilation, and also shade, as caterpillars do not like bright light.

In the case of each caterpillar kept, an illustrated record should be made of the stages in its life-history. Specimens may be identified by reference to such a book as *The Moths and Butterflies of the British Isles* (3 vols.), by R. South.

2. When a female butterfly or moth is reared, keep her alone for a time under a wire gauze cover near an open window, and keep watch the next few days to see whether the males from the country round will find her. Repeat some of J. H. Fabre's fascinating experiments,[2] and experiment yourself to find out by what sense they discover her.

[1] If collection is impossible, eggs, larvae or pupae can always be obtained from Mr. H. W. Head, entomologist, Scarborough, or from Mr. L. W. Newman, Bexley, Kent, or from other entomologists.

[2] *The Life of the Caterpillar*, by J. H. Fabre, chaps. xi., xii., and xiii.; also his *Social Life in the Insect World*, chaps. xiv. and xv.

CHAPTER XVIII

INSECTA (*continued*)

Order: Coleoptera (Beetles)

General Characteristics. The Coleoptera, or "sheath-winged" insects, all have four wings, but the front pair is modified to form horny protective sheaths, or *elytra*, which fit exactly over the upper surface of the body, showing only the tip of the abdomen, and completely covering the hind pair of membranous wings, which are used in flying. These wings, in beetles with strong flight, are much larger than the elytra, and when not in use they are creased and folded both longitudinally and transversely so that they fit in below the elytra.

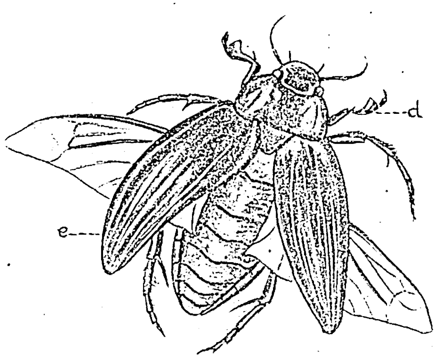

FIG. 188.—The Silver Water Beetle (*Hydrophilus piceus*), with the second pair of wings extended. (Drawn from dead specimen. Natural size.)

e, Elytra; *d*, triangular plate on the last joints of the tarsus, characteristic of the male.

The *mouth-parts* are modified for biting, there being very well developed mandibles. The central part of the lower lip is not divided as it is in the Orthoptera (Fig. 220). These insects undergo

a complete and great metamorphosis. The larva is sometimes a legless grub, but often there are three pairs of small thoracic legs; the pupa is soft, with no hard protective pupal case, and the organs of the imago show clearly through the thin pupal skin. This order is an enormous one numerically. It is reckoned that about 150,000 species are already known, and this number is constantly being added to; a little over 3000 of these are British.

On the whole, beetles are not such good fliers as most insects; indeed many of them use their wings but rarely, for they live mostly close to the ground where vegetation is dense and food plentiful. In some of these ground beetles the membranous wings are mere rudiments. A good many British forms are aquatic, and since the life-history of these is usually more easy to follow than that of the land forms, one of them will now be taken as the type for detailed study.

Sub-order 1: Adephaga (Beetles with Thread-like Antennae).

These forms are sometimes also known as the "Carnivora" on account of the nature of their food. The larvae as well as the adult beetles are exceptionally active and predaceous; the name of the sub-order means "the ravenous ones."

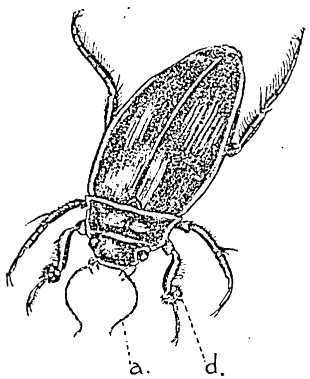

FIG. 189.—The Carnivorous Water Beetle (*Dyticus marginalis*). (Natural size.)
a, Antennae; *d*, disc on front leg, characteristic of the male.

Family 1: DYTISCIDAE

Type: The Carnivorous Water Beetle (*Dyticus marginalis*).

Dyticus marginalis is a large handsome beetle, very common in ponds, often seen at the surface as it tilts the tip of its abdomen out of the water to take in a fresh supply of air. If alarmed, it dives very rapidly down to the bottom, soon, however, floating up again, for its body is lighter than the water, and so it is unable to remain below except by active movement or by clinging

to some support. This beetle can be very easily kept in captivity, and will live for several years if well fed. Its natural food consists of tadpoles and soft-bodied larvae and even small fish, but it can be fed on "gentles,"[1] which it will devour eagerly. In spite of its carnivorous habits and strong mandibles, the beetle may be handled without any worse consequences than a possible prick from the two little sharp spines that are present on the under side of the body just between the last pair of legs, or a discharge of a bad-smelling fluid, either from just behind the head or, sometimes, from the end of the body.

Differences in Sexes.

The sexes are very distinct. In both, the body is about $1\frac{1}{4}$ inches long and of an olive-brown colour, with a light-brown border running all round the thorax and down the outer margin of the elytra; but whilst in the male the surface of the elytra is nearly always smooth, in the female each elytron is usually deeply furrowed ten or eleven times from the base for half its length. This distinction, however, is not quite invariable, and a safer guide is the curious disc which is always present on the front legs of the male only (Fig. 189, *d*); it is formed from the much-enlarged first three segments of the five-segmented foot or tarsus. When the under surface of this disc is examined, each segment is found to be beset with a number of small stalked suckers with two much larger ones on the first tarsal joint (Fig. 190). The terminal portion of each of these suckers, small or large, is slightly concave, and strengthened with radiating ribs; when it is firmly pressed on any surface, considerable suction results, though, according to Mr. Lownes's account,[2] this seems to be owing not merely to adhesion due to atmospheric pressure on the upper surface of the sucker,

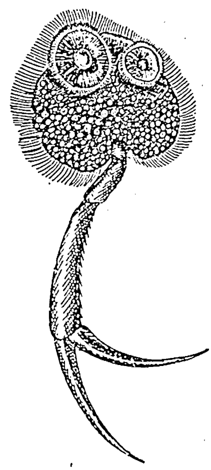

FIG. 190.—Tarsus from the fore-leg of a male *Dyticus*. (Magnified.)

Under-side, showing the disc formed from the first three segments of the tarsus.

[1] See p. 370.   [2] *Month. Micr. Journ.* vol. v., 1871, p. 267.

but also to an adhesive liquid that is given out by it. These adhesive discs seem to be used by the male in holding the female. The corresponding joints on the second pair of legs in the male are also slightly enlarged and capable of some adhesion. The back legs in both sexes are strongly feathered, and are the chief organs of locomotion.

The Head. The head bears compound eyes, which project but little, and a pair of long, delicate, jointed antennae. From the sides of the mouth are seen projecting two pairs of palps, and strong, toothed mandibles are also present.

Respiration. As has been mentioned above, the beetle always comes to the surface to renew its air supply. There is a space between the wing-covers and the abdomen, and this space is always filled with air, and into it, on each side, open eight spiracles, of which the last pair is specially large. When the beetle pushes its tail out of the water, air is taken in by these two last spiracles, and also the large air-bubble below the elytra is renewed; thus a store of air is obtained for use when the beetle is swimming below the surface. The silvery bubble of air is often to be seen extending backwards beyond the elytra. Although *Dyticus* spends most of its life in the water, it will occasionally fly, especially at night, and so it gets widely distributed. On the ground it is very awkward and helpless, jerking about in a very unsteady fashion.

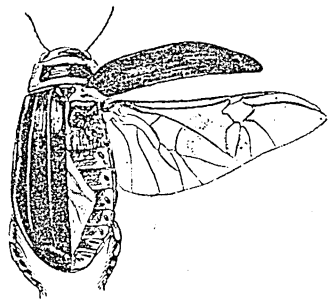

FIG. 191.—*Dyticus marginalis.*

Wing-cover and one wing pulled aside to show the eight spiracles down the right side of the body. (Natural size.)

Reproduction. In the spring, the female beetle lays her eggs, inserting them in a slit which she makes in the stem of some water plant (Fig. 192). The yellow-brown larvae hatch in about three weeks, and are full grown in another four or five weeks—an unusually rapid development.

The Larvae. The larvae of *Dyticus* are very common in ponds and ditches. They are the very fierce, active little creatures known to children as "toe-nippers." They kill

and suck the blood of a very large number of other soft-bodied inhabitants of the pond, and hence are often called "Water Tigers." They should never be brought home in a collecting tin with other creatures.

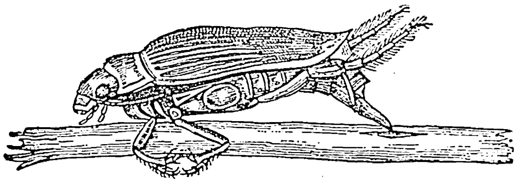

FIG. 192.—Female *Dyticus* laying eggs in the stem of a rush in which her ovipositor has made a longitudinal incision. (After Régimbart.)

The general form and characteristic attitude of the larva is shown in Fig. 193. The head is flat and bears six simple eyes on each side. The mouth is peculiar, being merely a horizontal slit between the upper and lower lips (labrum and labium), which is closed even when feeding. On either side of this is a curved, sharply-pointed mandible, having a minute tube running through it, open near the tip and again at the base.

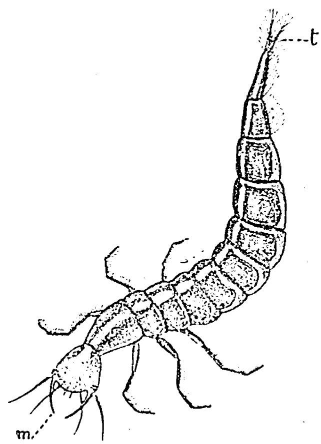

FIG. 193. — Full-grown Larva of *Dyticus marginalis* with mandibles, *m*, extended. (Nat. size.)
t, Tail appendages which float on the water surface when the beetle is breathing.

The larva seizes its prey with these jaws, and then quickly closes them over its mouth as far as possible. This action brings the basal opening of the tube into the corner of the otherwise closed mouth, and the blood of the victim is sucked into the mouth through the channel.[1] The larva feeds chiefly in this way, though apparently it can, by extending its mandibles widely, open the narrow slit-like mouth sufficiently to swallow small solid particles.

[1] For further details of the locking action of the mandibles, automatically closing the mouth, see Prof. Miall, *Aquatic Insects*, pp. 45-47.

The segmented body narrows down towards its eleventh or last segment, and bears terminally two fringed appendages (Fig. 193, *t*). When the larva floats up to the surface, with tail upcurved as in Figure 193, in order to take in a fresh supply of air through the two spiracles at the tip of the tail, these hairy appendages float out on the surface film and help to buoy up the body. Seven other pairs of spiracles are present down the sides, but they are closed. After having drawn in sufficient air, the larva, with a few vigorous strokes of the tail, swims down, and seizes the weeds with its jointed thoracic legs, and there lies in wait for its prey.

The Pupa. Late in the summer the larva leaves the water, and pupates in the damp earth near. It first excavates a little cell, then sheds its skin, and the pupa is displayed. This stage may last only a week or two if it is reached fairly early in the summer, but if late, the perfect insect will not emerge until the following spring. When first the pupal skin is discarded, the beetle is white and soft, and it is not until after some days that its skin turns brown and hard, and it takes its first flight into the air.

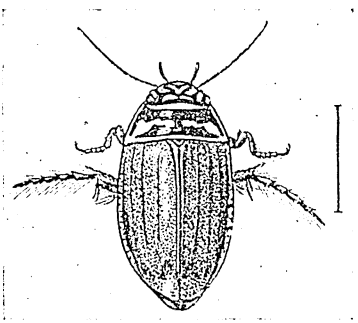

FIG. 194.—*Acilius sulcatus* (male). × 2. The first pair of legs is hidden below the body. The actual length is shown by the line to the right.

Other Water Beetles allied to Dyticus.

Acilius. Another very common water beetle closely allied to *Dyticus* is *Acilius sulcatus*, the "furrowed" Acilius. It is smaller than *Dyticus*, being about $\frac{5}{8}$ of an inch long, and it has a very flat body, yellow-brown above and darker underneath. It has peculiar black markings on the head and thorax (Fig. 194), and also some dusky spots near the hind end of the elytra. The sides of the abdomen may be spotted with yellow. As in *Dyticus*, the male has an enlarged disc on each of the front pair of legs, though these are usually carried tucked away under the body, and are therefore difficult to see; if, however,

the beetle is put on his back out of water and then touched, he will put them out to cling with them; the second pair also is hidden, except when the beetle is at rest, when they are extended in order to hold to the weeds; the third pair is used exclusively for swimming.

The male has usually smooth elytra, but in the female each has four broad, shallow furrows running their whole length, and lined with light brown hairs. When placed on its back out of water, this beetle will, if on a rough surface, spring up and over on to its feet with the greatest ease, sometimes with a curious "sizzling" noise. The larva is like that of *Dyticus* but smaller, and with a narrow first thoracic segment looking like a neck.

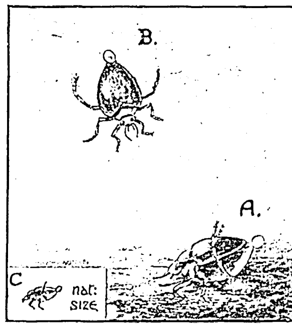

FIG. 195.—*Hyphydrus ovatus.*
A, Resting at the bottom of the pond; *B*, swimming down in the water.

Hyphydrus. A minute water beetle, often noticed because of its almost globular form and rusty red colour, is the *Hyphydrus ovatus*, with a body $\frac{1}{4}$ of an inch long or less.

Ilybius. *Ilybius* is a beetle common round London and in many other places. *Ilybius fuliginosus* is one of the commonest species; it can be recognised by its black, narrow body, convex above, and with a brownish-yellow streak down the outer margins of the elytra (Fig. 196).

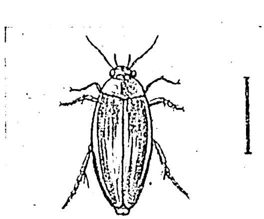

FIG. 196.—*Ilybius fuliginosus* (female) (the "Mud-dweller").

Screech Beetles (Pelobiidae). The Screech Beetle, or Squeaker (*Pelobius tardus*), is another common frequenter of ponds (Fig. 197). It is about half an inch long, and is well known because of the strange squeaking noise it makes by rubbing the hard rim of the last segment of the abdomen in a groove under each of the elytra. The beetle is a golden-brown colour (reddish when dead), and there is a

brownish-black patch over each eye, and along the front and back margins of the first thoracic segment, whilst a large black mark covers the hinder part of each of the elytra. The under side of the thorax and also of the hind end of the abdomen is black. The body is strongly convex both above and below, and consequently movement is difficult on the ground, though in the water the beetle is very active.

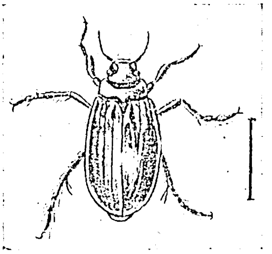

FIG. 197.—The Screech Beetle (*Pelobius tardus*).

The larva is aquatic and has a rather unusual appearance (Fig. 198). Its golden-brown body consists of a head and eleven segments, prettily marked above with dark brown. The

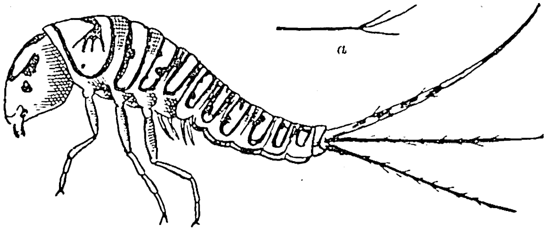

FIG. 198.—Larva of *Pelobius tardus*.
a, Line indicating real length.

last segment bears three long tail whisks, which are used to some extent in swimming, and which do not seem to be respiratory, for there are special little delicate respiratory filaments under the thorax and first three segments of the abdomen.

Tiger Beetles (Cicendelidae). The larvae and perfect insects of all the beetles so far mentioned have been aquatic and carnivorous; allied to them are the carnivorous **Tiger Beetles**, which live on land, and may be recognised by their broad heads with large eyes, their long thin legs, and blue-green or brown elytra spotted or marked with yellow or white. They have well-developed

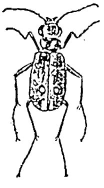

FIG. 199.—The Tiger Beetle (*Cicindela campestris*). (Natural size.)

membranous wings and fly readily. A common species on dry loose soil is *Cicindela campestris*, a terrestrial beetle that destroys a great many grubs harmful to plants (Fig. 199). The soft larva lies in wait for its prey in little vertical tunnels that it excavates in the ground, but the full-grown beetle is an active hunter, both on the ground and in the air; its body is about $\frac{3}{4}$ of an inch long, and of a beautiful green colour, spotted with white and yellow. The eggs are laid in the earth, where the larva lives its whole life, finally pupating at the bottom of its burrow. The curious bent form of the larva, and the pair of hooks at the back of the abdomen, of which it makes use when moving up and down in its burrow, are shown in Fig. 200. Clearly shown also is the strange, flattened form of the dark, horny head, on which the larva is said to carry up the earth from below as it excavates its burrow. This burrow may be a foot or more in depth, so that the larva expends a considerable amount of labour in forming it. When it is finished, the larva waits at the top of the burrow, closing the upper end with its horny head and thorax; immediately an insect crosses this pitfall, it is drawn down into the pit and there devoured.

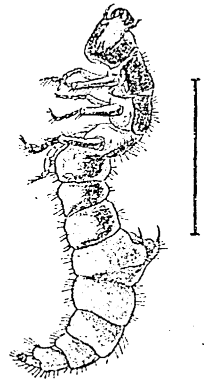

FIG. 200.—Larva of the Tiger Beetle, in natural position as in its burrow.

Ground Beetles (Carabidae). A great many land beetles have taken so entirely to a ground life that their wings have become more or less rudimentary, and their legs specially strong. Such forms may often be seen running about amongst grassy vegetation, or hiding under stones or moss. They have smaller heads than the Tiger Beetles and are usually black or a dark metallic colour. They are known as the Ground Beetles (*Carabidae*), and since they are carnivorous, they are valuable in a garden.

Carabus violaceus, the **Violet Ground Beetle,** is very common under clods of earth and damp logs. It is about an inch long and cannot open its fused elytra. This is a useful beetle, for it feeds largely on the Cutworms that are so injurious to crops (see page 265).

Pterostichus madidus is another ground beetle very frequently exposed whilst gardening. It is about $\frac{3}{4}$ inch long and of a shining black except for its reddish-coloured legs; the elytra are longitudinally grooved and are fused together.

Brachinus crepitans, the little "Bombardier Beetle," is only just over $\frac{1}{4}$ inch long, and has a red head and thorax and blue-black wing covers. It is noted for its habit of ejecting from its body, when alarmed, a fluid which at once volatilises with a little explosion. It is common on the chalk downs of the South of England.

Classification of Beetles.

All the beetles so far described have had simple, threadlike, jointed antennae. The next three sub-orders to be considered have variously modified antennae, usually with the last few segments thicker than the rest (club-shaped or clavicorn), or with the segments extending laterally on their inner sides, so that the antennae appear serrate (serricorn). In others, again, the antennae have their last joints enlarged to form leaf-like plates or lamellae (lamellicorn). For convenience, this classification into *clavicorn*, *serricorn*, and *lamellicorn* forms will be adopted here, with a further subdivision according to habitat, the group being too enormous for a more scientific classification to be useful here, where only a very few forms can be described.

Sub-order 2: Clavicornia.

Garden Beetles with Clubbed Antennae (Clavicorn Beetles).

Ladybirds (Coccinellidae).

Ladybirds are perhaps the best known, and also some of the most useful of beetles to the gardener, for throughout their lives they feed on the green-fly (*Aphides*) that do so much harm by sucking the juices of plants (see p. 318). The adult beetle, with its brightly coloured body, usually red with black spots, is constantly to be seen from early spring till late summer. The conspicuous coloration may be considered as serving a protective warning function, for a yellow fluid of disagreeable smell and taste issues from the joints of the legs, so that the insect is distasteful to birds. The upper side of the body is very convex, and so curved that from above little of the head can be seen. The antennae are very short and slightly

clubbed. There are two species which are particularly common—the "two-spotted" and the "seven-spotted" ladybirds.

FIG. 201.—The Two-spotted Ladybird (*Coccinella bi-punctata*).
Different stages in its life-history, on a rose-twig: *i*, imago; *p*, pupa; *l*, larva; *g*, green-fly on which the larvae are feeding. (Natural size.)

They lay their little clusters of yellow eggs on some plant infested by the *Aphides* on which they feed.

The larvae which hatch out are active little six-legged creatures, which hunt the green-fly and devour them voraciously. In two to three weeks' time, if food is plentiful, the larva is full grown, and is then longer than the beetle; it has a rough, dark-grey body, spotted with black and yellow (Fig. 202). It now suspends itself from a leaf by means of a sticky secretion given out by the tail. The larval skin splits at the head end, and is pushed down and off the body. The pupa form within swells to a blunt, angular body, which moves when touched (Fig. 201, *p*); it is a deep yellow colour at first, but it soon darkens. From this pupa the perfect insect emerges in about ten days.

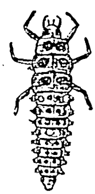

FIG. 202.—The Larva of a Ladybird.
(Enlarged.)

The Cock-tail Beetles (Staphylinidae).

The Cock-tail Beetle, or "Devil's Coach-horse" (*Ocypus olens*), is one of the "Rove Beetles," which feed on insects and worms; they are frequently to be found roving about on footpaths and roads,

perhaps on their way to new hunting grounds. This beetle is a dull black with a slight red tinge at the end of the antennae. It and all members of its family have peculiarly short elytra in spite of the well-developed membranous wings, which have to be much crumpled up to get them securely beneath the elytra. In consequence of the shortness of these, the abdomen, which is very easily movable, can be curled up (Fig. 203), and this is so continually done that the beetles have gained permanently the name of "Cock-tails."[1] The larva lives underground and is not often seen.

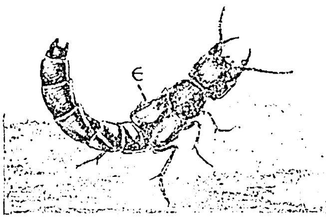

FIG. 203.—The Cock-tail Beetle (*Ocypus olens*). (Natural size.) *e*, The short elytra.

There are many other British *Rove-Beetles*, all easily distinguished by their short elytra. The Red Rove Beetle is very common. *Lomechusa strumosa* is a small rare beetle found in the nest of the Blood-red Ant (page 459).

Burying and Carrion Beetles (Silphidae).

The *Silphidae* includes the well-known **Burying or Sexton Beetles** (*Necrophorus*) as well as the **Carrion Beetles** (*Silpha*). Most of the genus *Necrophorus* are gay in their attire, having a double red band across the elytra, but *N. humator*, a form an inch long, is clothed in funereal black, and is therefore known as the "Black Burying Beetle" to distinguish him from the slightly smaller and more cheerful-looking "Sextons." These beetles are quickly attracted by the presence on the ground of the dead body of some small animal such as a mouse, and at once they begin to excavate the soil from below it so that it gradually subsides, and in time becomes covered by the soil which slips down over it as it sinks. In the decaying body the mother beetle lays her eggs, and when they hatch, the little grubs feed on the horrible food they find all around them until they are ready to pupate, when they burrow into the earth, making little cells for themselves.[2]

[1] See "An Interview with a Devil's Coach-horse Beetle," in *Insect Biographies*, by J. J. Ward.

[2] For experiments on instinct in these beetles, see Fabre's *Wonders of Instinct*.

The Carrion Beetles (*Silpha*) are mostly about $\frac{1}{2}$ inch long; usually they have black, oval bodies, though the "Four-spot Carrion," which is common in oak woods in the South of England, is yellow with black spots. They eat the dead bodies of small animals without first burying them, though here too the carcase serves as a home for eggs and larvae.

Aquatic Beetles with Clubbed Antennae.

Type: The Silver Water Beetle (*Hydrophilus piceus*).

Some of the beetles with club-shaped antennae are aquatic; the largest of these is the Silver Water Beetle (Fig. 204), a form which used to be fairly common round London, but is now becoming scarce. It is a very dark green, almost black, dorsally, though in the water the thorax and front part of the abdomen appear silvery beneath, owing to the film of air held by the closely-set, short hairs which cover this part of the body. The air film also extends on the dorsal side round the neck and between the thorax and elytra. The beetle swims rather irregularly in the water, using the legs of the two sides alternately, instead of together as in *Dyticus*. The two back pairs of legs are large and feathered and are used in swimming, whilst the front legs are much smaller. In the male, the last joint of the foot (*tarsus*) is flattened out into a triangular plate (Fig. 188, *d*).

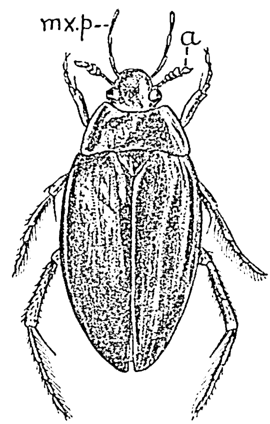

FIG. 204.—The Silver Water Beetle (*Hydrophilus piceus* ♀).

Drawn from dead specimen with antennae, *a*, spread out (in life they would be hidden in this view); *mx.p*, maxillary palp.

Below the long elytra are large membranous wings (Fig. 188), by the aid of which the beetle flies from pond to pond, usually at night. On the ventral surface the body slopes to a ridge in the middle line, and the thoracic ridge is prolonged behind

into a strong spine, which sometimes inflicts a prick when the beetle is handled.

Respiration. Like *Dyticus*, *Hydrophilus* has to come to the surface to breathe, but whilst the former tilts its tail up into the air, and takes in its fresh supply through the abdominal spiracles, refilling the air space below the elytra from behind, the Silver Water Beetle swims to the surface and lies there almost horizontally, just lifting one "shoulder" out of the water and opening a little air passage between the head and thorax; this passage is bounded on its outer side by the curiously curved antenna, the end joints of which are densely covered with hairs which prevent the water from obtaining entrance.[1] The air passes through this channel and along the air films at the sides of the thorax and abdomen, and so into the thoracic and large first abdominal spiracles; at the same time the large reservoir of air below the elytra is renewed for use later on, when the beetle is submerged again. There is a row of spiracles on either side of the abdomen opening into the dorsal air reservoir. When the beetle is at the surface, the interchange of air is assisted by the rhythmic movements of the elytra, which alternately lessen and increase the capacity of the air reservoir.

Food. These beetles feed chiefly on various water-weeds, but apparently they are also carnivorous to a slight extent, though they only attack quite small creatures.

Reproduction. In April, the female *Hydrophilus* may be seen at the surface of the water, where the vegetation is fairly thick, preparing the cocoon in which she lays her eggs.[2] She has at the end of her body two tubular spinnerets from each of which a silk thread issues, and, clinging to the weeds upside down, she weaves a little concave sheet of silk which just covers the upturned lower surface of her abdomen, attaching the silk to a floating leaf; then, turning over, she weaves a similar piece, and joins the two together into a cocoon closed at one end (Fig. 205).

[1] For a very clear, detailed account of the process, refer to *Aquatic Insects*, by Professor Miall.

[2] As I have not yet had the good luck to watch this whole process, the following description is taken from Lyonnet, *Mémoires du Muséum*, vols. xviii.-xx., and from Miger's account in the *Ann. du Muséum d'Hist. Nat.* tom. xiv., 1809.

She keeps her abdomen hidden inside this cocoon, and for the next two hours she lays neat rows of eggs in it, until about fifty or sixty eggs hang vertically from its roof, with their pointed ends uppermost and with an air space below them. When this process is completed, she begins to close the open end by spinning fresh threads round it; finally a little upright hollow spike is woven which may project nearly an inch above the water (Fig. 205, *s*). The function of the spike may be to form an air channel from the air above, down to the eggs. It is, however, closed at the end, consequently air can only enter it by diffusion. The cocoon when finished is firm and watertight.

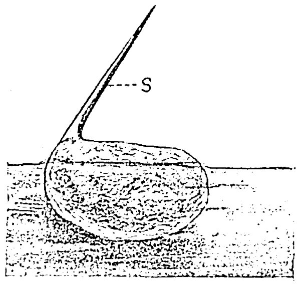

FIG. 205.—The Egg-cocoon of the Silver Water Beetle. (Nat. size.)
s, Hollow spike.

The Larvae. The larvae, when they hatch, stay for about twelve hours inside the cocoon, and then make their way into the water as soft, grey-coloured grubs, with black heads and strong jaws, with which they bite the animal food that they now favour—usually small snails and tadpoles. They have to come to the surface to breathe, taking in air through spiracles at the end of the tail. They grow very quickly, and in a few weeks, if well fed, the larva leaves the water and pupates in the earth, inside an oval cell which it excavates. The perfect insect, when it emerges from the pupa, remains underground for a day or two, and then forces its way out of the earth and flies to a pond. Except for occasional migrations from one pond to another, it spends the rest of its life in the water, lying dormant at the bottom of the pond during the winter.

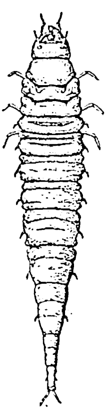

FIG. 206.—Larva of the Silver Water Beetle. (After Miall.)
(Natural Size.)

The Whirligig Beetles (Gyrinidae).

The Whirligig or Shiner Beetles are classed with the Clavicorn beetles, since their antennae are short and slightly club-shaped. They occur in great numbers in ponds, especially in the early autumn. The commonest species, *Gyrinus natator*, is only about $\frac{1}{4}$ of an inch long, and its body is convex above and flat below. It has a remarkably shiny, blue-black body, and it darts about in the sunshine at the surface of the water with great rapidity, constantly turning and twisting, and so earning the name of "Whirligig." If disturbed, it swims to the bottom of the water and clings to a weed, until it is obliged to float to the surface again for more air. As it swims, a shining bubble of air is often to be seen clinging to the end of the body. The two back pairs of legs are short but broad, fringed with hairs, and are used in swimming, the front pair being used for holding. In the male the tarsal joints are enlarged. These "Whirligigs" seem to have two pairs of eyes, for each compound eye is divided into an upper half, which views the surface of the water, and a lower half, which is submerged and looks through the water.

FIG. 207.—The Whirligig Beetle (*Gyrinus natator*). × $3\frac{1}{2}$.

These beetles feed on water plants and minute water insects, occasionally flying from pond to pond; they hibernate on the mud at the pond bottom. Eggs are laid in the spring on some submerged plant, and the larvae hatch within a fortnight; they may be but little more than half an inch long, and each has a head and twelve segments. The three thoracic segments bear ordinary jointed legs, and each of the first eight abdominal segments bears a pair of delicate feathered "tracheal gills," whilst the last segment bears two pairs of such gills. The larva is carnivorous, but will at times feed on water plants. It swims actively with a serpentine motion.

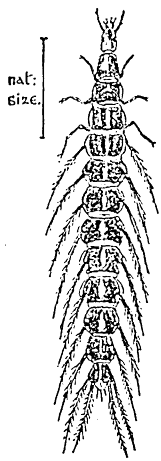

FIG. 208.—The Larva of the Whirligig Beetle.

After a while it leaves the water, and is said to pupate on some plant which grows above the water surface, spinning for itself a little silk cocoon well hidden amongst the foliage and very rarely seen. The imago emerges in August or September.

Sub-order 3: Serricornia.

Garden Beetles with Serrate Antennae.

Skipjacks or Click Beetles. (Elateridae.) In the **Skipjacks**, or **Click Beetles**, the form of the antennae is very variable. It may be serrate—made up of little triangular pieces, which project most on the inner side of the antenna—but it is thread-like in just a few beetles, which, however, because of their resemblance in other points, are also classed here. A curious feature in the anatomy of Click Beetles is the elongation of the first segment of the thorax on its under side into a central spine (Fig. 209, *s*), which points backwards and fits into a groove in the second segment. If the beetle is put on its back, it arches up its body (Fig. 209, *A*) so that only the front of the thorax and ends of the abdomen and elytra touch the ground, and the spine just rests on a ridge above the groove; then it suddenly contracts the muscles, so that the spine is forced past this ridge into the groove, with a click; this sudden movement causes the arching of the body in the reverse direction, and the tips of the elytra strike the

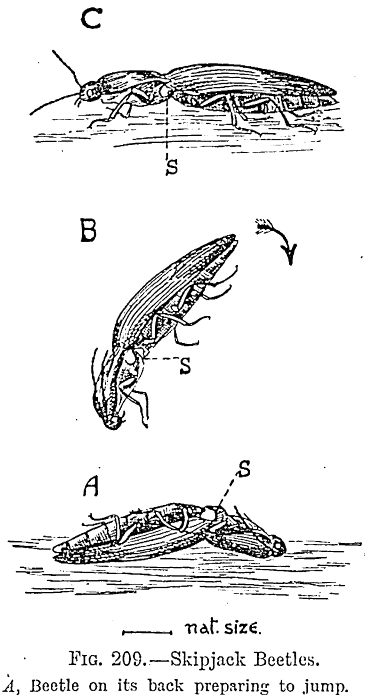

FIG. 209.—Skipjack Beetles.

A, Beetle on its back preparing to jump. *B*, Jumping and at the same time reversing its position as a result of its action in position *A*. *C*, Beetle once more on the ground after having been in positions *A* and *B* successively. *s*=spine.

ground with such force that the recoil jerks the body two or three inches into the air, usually reversing its position at the same time, so that the beetle alights on its feet (Fig. 209, *C*).

The larvae of these beetles are the troublesome "wire-worms" which live in the ground, and some species of which do great damage to the roots of plants. They are small,

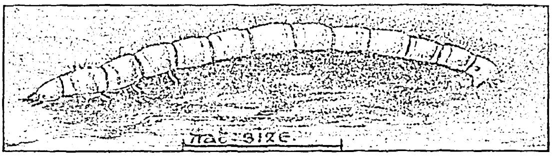

FIG. 210.—The Wire-worm or Larva of the Click Beetle. (×3.)

yellow, rather stiff creatures, with an elongated, thin body of the same thickness throughout its length, and with six short insignificant legs and a process projecting downwards from the last segment which serves as an extra foot.

Glow-worm Beetles (Lampyrides). The Glow-worm Beetle (*Lampyris noctiluca*) is a small beetle about a third of an inch long, noted for the intermittent luminous glow given out from below the last three segments of the abdomen. This characteristic is specially noticeable in the wingless, dark-coloured females, and is used in attracting their mates. Fabre describes how at the mating season the females climb a stalk and jerk their tails up first in one direction and then in another, flashing their little signal lights to the winged males who are flying overhead; he is a little smaller than the female, and is only slightly luminous, having only two little dots of light on the last segment of his body. The egg and the larva also exhibit a faint glow. The larva is very like the female in form, but is slightly narrower, and has a row of light marks down each side of the back (Fig. 213). This beetle is only active at night, and is most

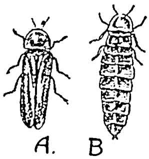

FIG. 211.—Glow-worm Beetles.

A, Male; *B*, female. (Life-size.)

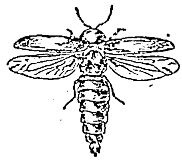

FIG. 212.—Male Beetle with wings outspread. (Slightly enlarged.)

usually found on a damp, grassy bank. It should be encouraged in gardens, for the larva eats small snails, first "chloroforming" his victim, according to Fabre, by several little poisonous nips with his jaws and then sucking up its juices.

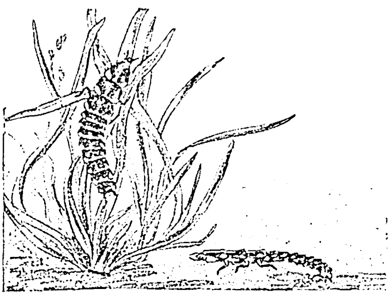

FIG. 213.—Larvae of Glow-worm Beetles.

The European **Fire-flies** are closely allied to our glow-worms. In them the males also are brightly luminous and go about in swarms, adding a great charm to the summer nights. The females of this fire-fly are said to be very rarely seen.

The Furniture Beetles (Ptinides). The ravages of the **Furniture Beetle** (*Anobium striatum*) are only too well known, for it is the cause of "worm-eaten" wood, the "worm" being the little white larva, which, with the aid of a pin, can sometimes be extracted without difficulty from a hole in an old piece of furniture. The larval, wood-eating stage is said to last for three years; after the pupal stage a little dull-brown beetle, about $\frac{1}{8}$ of an inch long, makes its way out of the wood. It has a queer, rounded shape, and its head and legs can be tucked away below the body, so that it appears inanimate and is easily overlooked.[1]

Anobium domesticum is the "Death Watch Beetle," which also lives in old wood; the ticking noise made by it, to which has been ascribed an uncanny prognostication of the approach of death, is really the signal of the little male desiring a mate; it is a presage of life rather than death. He is beating with his horny "shoulders" on the sides of the tunnel in which he lives, and in response a similar "beat" or "tick" may come from a neighbouring tunnel.

[1] The "worm" can sometimes be destroyed in worm-eaten furniture by washing thoroughly with benzine every day for a week, or, where possible, by merely wrapping the infected wood in rags well soaked with paraffin oil and leaving out in the open air for two or three weeks. I have entirely cured badly infected wood in this way.

Sub-order 4: Lamellicornia.

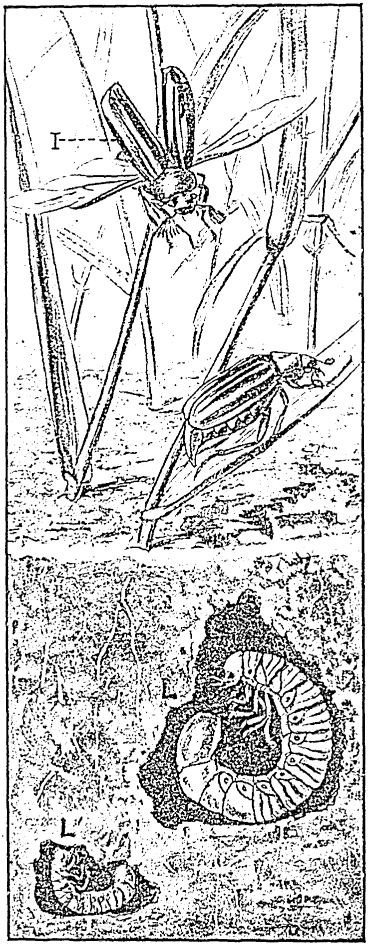

FIG. 214.—The Common Cockchafer (*Melolontha vulgaris*).

I, Male cockchafer; *L'*, young larva; *L*, older larva. (Natural size.)

The Cockchafer (Scarabaeidae). One of the best known of the Lamellicorn Beetles is the **Common Cockchafer** (*Melolontha vulgaris*), in which the antennae are markedly "lamellicorn," those of the male having seven leaflets, whilst the female has only six. These insects are very common in the early summer, especially during the month of May. They rest during the heat of the day amongst the leaves of trees, and come out chiefly in the early evening and early morning, flying with a heavy, clumsy flight. They feed on the leaves of many common forest trees, and although their life as winged insects only lasts for six weeks, they may, if they are numerous, do very great damage to the trees.

Life-history. At the end of May or beginning of June, the female Chafer lays small, yellowish eggs in two or three little clusters of ten or fifteen at a time, each cluster being hidden away in a hole which she excavates in the earth two or three inches down. In five or six weeks the

larva hatches, and for two or three years it lives underground, feeding at first on decaying organic matter in the soil, but later attacking the roots of plants with its strong jaws, and thus doing much damage. The *grubs* are soft, white creatures with dark, horny heads and no eyes. They have six weak, black legs, but all power of movement in these is soon practically lost. They hibernate in the soil, lying coiled round as in Fig. 214. The duration of the larval stage varies slightly in different countries, but in England it is usually during the third summer of its life that the larva burrows a little deeper in the ground and pupates for a short while. The perfect insect then throws off its pupal skin, but it still remains underground until the following April or May, so that the beetle is nearly three years old when it first emerges into the air and light, and with a humming noise flies to the trees.

An allied form is the beautiful metallic-green **Rosechafer.** This beetle is about $\frac{3}{4}$ inch long, and is very destructive to roses, eating the centre of the flowers.

The Dor Beetles (Scarabaeidae).

The Dor Beetles or "Dumble-dors" (*Geotrupes*) are related to the Chafers, and, like them, fly at night, with a strong blundering flight, humming as they go; often a Dumble-dor will collide with some object and sometimes will fall to the ground, where he will lie helplessly on his back, kicking his legs, apparently quite unable to get up again in spite of his strong thoracic muscles, which make it quite a difficult matter to hold him securely.

These beetles are black or blue-black or bronze in colour, and have thick, rounded bodies $\frac{1}{2}$ to 1 inch long; they may be found under patches of cow or horse dung, below which they excavate their vertical burrows in the earth: a pair work at this together, and then the female excavates one or more oval horizontal chambers leading off at different levels from the vertical shaft; in each of these she packs away a ball of the dung brought down to her by her mate, and in or on this she lays an egg; the larvae when they hatch feed on the material thus stored for them and pupate in the earth. Dor Beetles are often found nearly covered below with numbers of the little yellow mite *Gamasus*, which may, as suggested by J. J. Ward,[1] perform a useful function in keeping the polished, horny skin of the beetle clean.

[1] *Insect Biographies*, by J. J. Ward.

Geotrupes stercorarius is the commonest Dor Beetle. The male of *G. typheus* is peculiar in having three forwardly projecting processes on his thorax. The Sacred Scarab also belongs to this family but is not British.[1]

Stag Beetles (Lucanidae). The Stag Beetles (*Lucanus cervus*), the largest of all British beetles, are also lamellicorn. They have dark-brown bodies, and fly chiefly in the evening. The male may be over two inches long, and he is very formidable-looking because of the enormous enlargement

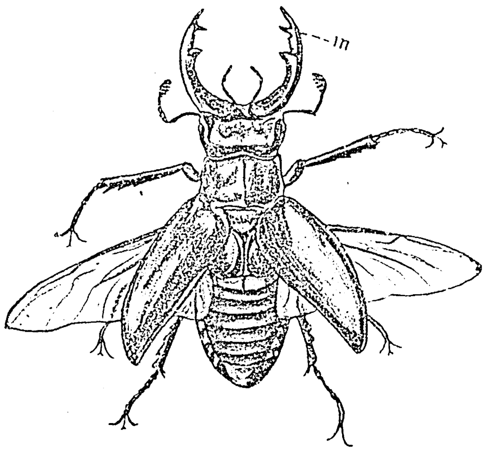

FIG. 215.—The Stag Beetle (*Lucanus cervus*). Male. (Natural size.)
(Drawn from a dead specimen; the parts are therefore rather unnaturally extended.)

of the antler-like mandibles (Fig. 215, *m*), but these apparently are only used in fighting contests to gain a mate, and the beetle feeds most harmlessly on the sweet juice which exudes from oak trees. The female Stag Beetle is much smaller than the male. The larva is much like that of the Cockchafer, but lives for about four years in the decaying wood of the trunks of trees. When full grown it makes a cell in the rotten wood and pupates there. The beetle, which emerges in the winter, stays within its cell until the following June, when it pushes its way up to the air and light.

[1] For an account of this see *Insect Life*, by Fabre (published by Macmillan, price 9d.).

Sub-order 5: Rhyncophora (Snout Beetles).

In all the Snout Beetles the head is lengthened in front into a characteristic snout or beak, also the foot (tarsus) is typically four-jointed. The number of these beetles is enormous, including about 25,000 species. The Weevils and the Bark Beetles are perhaps the best known of them.

Weevils (Family Curculionidae). The Weevils constitute a very large assemblage of forms, many of which are serious pests. They can always be recognised by the snout or beak (rostrum) that projects in front of the head, and also by the antennae, which are usually very distinctly "elbowed," *i.e.* each has a long basal joint which can be extended outwards at the sides of the head, whilst the other, terminal joints turn forward and are thickened at the tip (Fig. 216).

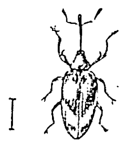

FIG. 216.—Apple-blossom Weevil (*Anthonomus pomorum*).

The tarsus appears to be four-jointed only, but in some cases another, very small joint can be detected.

Weevil larvae are legless; they feed on very various substances; one, a very short-snouted form, the **Pea Weevil**, lives in ripening peas, and the larva on emerging makes the little circular holes often noticed in them. Another, the **Nut Weevil**, which has a long snout, lives, when a larva, inside hazel nuts. Another attacks the flower-buds of fruit trees, especially the apple. Again, the felled wood of pine trees, stored grains of wheat, the roots and stalks of turnips and cabbages, and parts of many other plants are attacked by these voracious creatures.

The Birch Weevil (Fig. 217) is one of the most interesting, because of the clever way in which it cuts a leaf from margin to midrib on both sides, and then rolls the lower part into a narrow cone to protect the eggs which it lays within, closing the cone at its lower end by rolling the tip and tucking it in —a wonderful case of an inherited complex instinct, the evolution of which it is extremely difficult to understand. The blind larva lives inside the funnel until it is full grown, feeding on the leaf.

The Common Bark Beetles (Scolytidae). A common Bark Beetle is *Hylesinus fraxini*, which occasionally does much damage to ash trees. It is a tiny beetle, which bites through the bark of

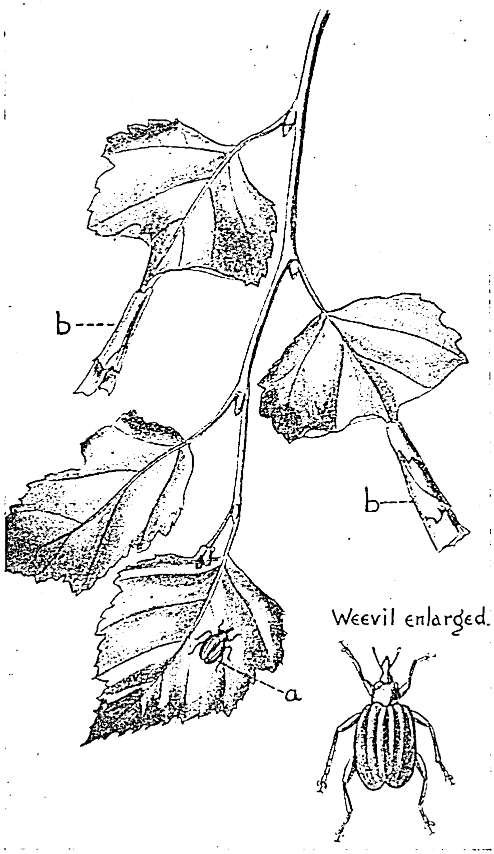

FIG. 217.—The Birch Weevil (*Rhynchites betulae*).

a, The full-grown insect, natural size; *b*, the birch leaf rolled by the weevil.

the tree, and then excavates a little horizontal tunnel in the wood just inside the bark (Fig. 218). In small bays in the side of this tunnel the beetle lays her eggs, and the maggot-

like larvae which hatch out feed on the tissues of the wood, eating little tunnels which pass out at right angles to the mother tunnel, as shown in the diagram. In the enlargement at the end of each secondary tunnel one larva pupates. It emerges as a fully developed beetle the following spring, leaving the tree by a fresh tunnel which it makes through the bark.

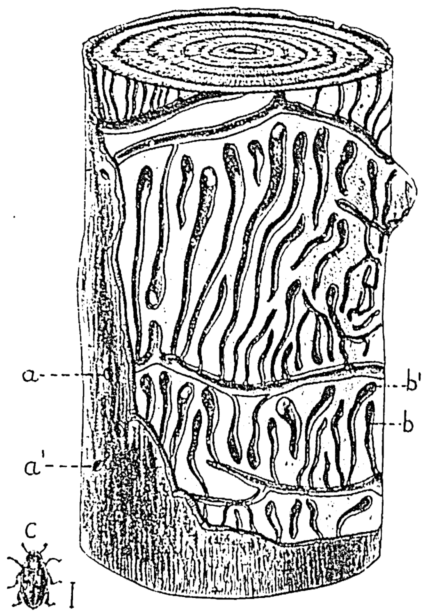

FIG. 218.—The Bark Beetle (*Hylesinus fraxini.*)

a, Entrance to horizontal tunnel made by the mother beetle; *b*, vertical tunnel made by her offspring; *b'*, cell in which the larva pupates; *a'*, a hole through which a young beetle has emerged; *c*, one beetle enlarged.

Sub-order 6: Phytophaga.

The beetles of this sub-order are also all plant-eating, but they have no snout and the antennae are not clubbed.

Longicorns (Cerambycidae). The beautiful metallic green **Musk Beetle** (*Aromia moschata*) is one of the Longicorns. It is an inch in length and has long, straight-sided elytra and beautiful antennae as long as the body. It is found on decaying willows, in the stem of which it lays its eggs. In captivity it seems much to relish a slice of apple, which it nibbles, and also it drinks water eagerly. It has a pleasant scent of musk or sweet-brier.

Strangelia armata is the little beetle often found on flowers; its body is about $\frac{1}{2}$ inch long and is all black, but it has yellow elytra with black markings on them. The specific name refers to the little spines, one on each side of the thorax.

Chrysomelidae. These beetles differ from the Longicorns in their much shorter antennae, the bases of which are not surrounded by the eyes. They feed usually on leaves. **The Lily Beetle** (*Crioceris merdigera*) eats lily leaves, and the little coral-red mother lays her eggs in the central developing shoot of the plant. The larvae feed on the young leaves, forming a case round themselves of their own excrements—a strange protection!

The Asparagus Beetle (*C. asparagi*) sometimes does great damage in asparagus beds.

The genus *Donacia* consists of little gold, blue or green beetles that live in the air, but can enter the water to lay their eggs on water-plants, often on water-lilies. The beetles vary from $\frac{1}{3}$ to $\frac{1}{2}$ inch long; the larvae make burrows in the roots of the water-plants, tapping the air-vessels of the plant in order to obtain air for their own respiration.[1]

General Classification of Beetles mentioned in Chapter XVIII.

Order. COLEOPTERA.

Sub-order 1.—**Adephaga.** (The "Gluttons.") Predatory beetles with thread-like antennae, larvae active and predatory.

- Family 1. Dytiscidae. The Carnivorous Water Beetles.
  Dyticus. Acilius. Hyphydrus. Ilybius.
- Family 2. Pelobiidae. The Screech Beetles.
- Family 3. Cicindelidae. The Tiger Beetles.
- Family 4. Carabidae. The Ground Beetles.
  Carabus. Pterostichus. Brachinus.

Sub-order 2.—**Clavicornia.** Antennae usually thicker at the tip, though the thickening may be slight.

- Family 1. Coccinellidae. Ladybirds.
- Family 2. Staphylinidae. Cock-tail or Rove Beetles.
  Ocypus. Lomechusa.
- Family 3. Silphidae. Burying and Carrion Beetles.
  Necrophorus. Silpha.
- Family 4. Hydrophilidae. Silver Water Beetles.
- Family 5. Gyrinidae. Whirligig Beetles.

Sub-order 3. **Serricornia.** Antennae usually serrate—not a very coherent sub-order.

- Family 1. Elateridae. Click Beetles.

[1] *Camb. Nat. Hist.*, *Insects*, Part II. p. 280.

Family 2. Lampyrides. Glow-worm Beetles.

Family 3. Ptinides. Furniture Beetles.

Anobium.

Sub-order 4.—**Lamellicornia.** The antennae have their last joints enlarged to form horizontal, leaf-like parts.

Family 1. Scarabaeidae. Cockchafers, etc.

Melolontha. Geotrupes.

Family 2. Lucanidae. Stag Beetles.

Sub-order 5.—**Rhynchophora** (The Snout Beetles). The head is prolonged in front to form a beak or "snout."

Family 1. Curculionidae. Weevils.

Anthonomus. Rhynchites.

Family 2. Scolytidae. The Bark Beetles.

Hylesinus.

Sub-order 6.—**Phytophaga.** The plant-eating beetles with no snouts.

Family 1. Cerambycidae (Longicorns).

Aromia (Musk Beetle). *Strangelia.*

Family 2. Chrysomelidae.

Crioceris. Donacia.

Practical Notes

1. Get male and female specimens of *Dyticus marginalis* and keep them alone in a fairly large fresh-water tank with plenty of water-weed. Feed on "gentles." In the spring, be on the look-out for egg-laying, and if this is detected, remove the eggs, with the water-plant in which they are inserted, to a smaller tank and watch their development. If eggs cannot be obtained, larvae should be caught from the ponds and their development watched. Great care must be taken to give the full-grown larva a suitable earth bank rising above the water, in which it can pupate.

2. Keep the Silver Water Beetle in the same way. This beetle feeds almost entirely on water-weeds, and can be kept, therefore, in a tank with other creatures, though in the spring it is well to keep one tank for these beetles alone, so that the formation of the egg-cocoon in May may be seen.

3. Collect from the ponds any other water beetles or beetle larvae obtainable. Keep them carefully apart, and identify them speedily, so that their ways may be ascertained and suitable food given them. Their life-histories may then be worked out.

4. Search any plant which is infested with Green-fly for Lady-bird eggs, larvae, pupae, or full-grown beetles. Isolate one larva on a twig covered with Green-fly, and determine at what rate the larva devours them. Work out the life-history in detail, making careful illustrations of each stage.

5. Study any other live Land Beetles that are available, keeping careful records of your observations, even when incomplete. It may be possible to complete them at a later date. Specimens may be identified by reference to such a standard work as *British Coleoptera*, by W. W. Fowler (now out of print), or *Handbook of Coleoptera of Great Britain and Ireland*, by H. E. Cox (published by Janson & Sons, Great Russell Street, 21s.).

British Beetles, by E. C. Rye and W. W. Fowler (Reeve & Co., 1890), and *Common British Beetles*, by C. A. Hall (Black, 1914), are useful, smaller books, with coloured plates.

6. Read the account of how to rear Dor Beetles given by Miss Hibbert Ware in *School Nature Study* for October 1921 (published by G. Philip & Son).

7. Read Fabre's account of Burying Beetles and the Glow-worm in his *Wonders of Instinct*, and repeat some of his experiments.

8. Read also Fabre's account of the Sacred Scarab given in *Insect Life* (Macmillan, price 9d.).

9. Read the chapters on Beetles in *Insect Biographies*, by J. J. Ward.

10. Make a "subterrarium," as described in Appendix D, in which to rear beetles and other underground creatures.

CHAPTER XIX

INSECTA (*continued*)

Order: ORTHOPTERA (COCKROACHES, GRASSHOPPERS, AND EARWIGS [1])

General Characteristics. THE Orthoptera, or "straight-winged" insects, like all the insect orders, are distinguished by special wing characteristics. They have two pairs of wings; the first pair is usually somewhat harder and stronger than the second, and is laid flat over the back, forming a case over the other wings, which are membranous and used in flying. The front wings, therefore, recall those of Coleoptera, but the back wings are different and are specially characteristic; each is elaborately folded, the parts closing on one another like the segments of a fan; this folding in straight segments has given the name Orthoptera [2] to the order. Occasionally, however, where the back wings are relatively very large, they may have one or two transverse folds as well. In many species the wings are rudimentary or absent. The Orthoptera also differ from the Coleoptera, or true beetles, in the gradual metamorphosis of the larva into the adult form—there being no quiescent pupal stage as there is in true beetles. The mouth-parts are adapted for biting; there is a pair of hard mandibles, and both on the soft jaws (maxillae) and on the labium (Fig. 220) are conspicuous soft palps. The last segment of the abdomen usually bears a pair of many-jointed, antenna-like processes called *cerci*, which are replaced in adult earwigs by the unjointed *forceps*.

[1] Earwigs are classified as a separate order, Dermaptera, by Prof. G. H. Carpenter (see *Insect Transformation*), but this change is not adopted here.

[2] Greek, *orthos*, straight; *pteron*, a wing.

Sub-order 1 : Cursoria (The Running Orthoptera).

Family 1 : Blattidae

Type : The Cockroach (*Blatta Orientalis*).

The almost universal antipathy felt towards the so-called "black-beetle"—which is, however, neither black nor a beetle —is due to the fact that it often becomes a pest in old houses; yet, if we overcome this first natural repugnance, there is much to admire in the various adaptations of its body structure, even if we cannot get so far as the writer in the *Cambridge Natural History*, who speaks of it as a "rather amusing pet"!

Differences in Male, Female, and Larva.

The form most usually to be seen scurrying over the floor to escape our onslaught is the female cockroach, which has small rudimentary wing-covers and no membranous wings at all, but a relatively

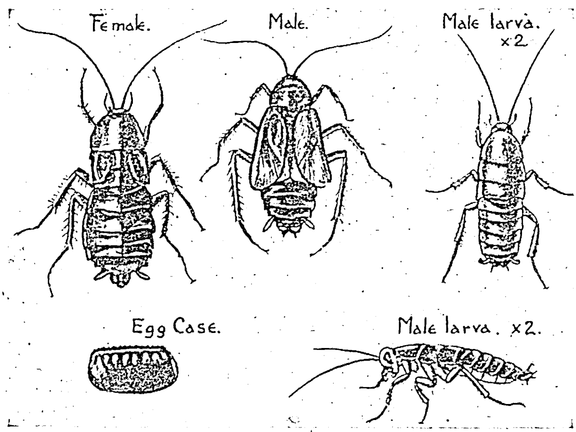

Fig. 219.—The Common Cockroach.

large body (Fig. 219). The male is shorter and has a well-developed second pair of membranous wings lying below the upper pair of stiffer wing-cases, and he is able to fly, though rarely seen in the act. The young larva has no trace of wings, and it is said that four years elapse before it becomes fully developed. Immature Cockroaches are always paler in colour than the adults.

General Structure. In all stages the flattened form of the body is noticeable, and also the curious position of the head, which is turned downwards (see Fig. 219), so that very little of it can be seen when viewed from above. The head bears a pair of long, very flexible, many-jointed antennae, a pair of compound eyes, and a mouth surrounded by appendages, as shown in Fig. 220. The insect cleans its antennae by dragging them between its jaws.

The *thorax* has the usual three segments, but the first of these has a more independent motion than is general in insects, owing to the specially free articulation between it and the second segment.

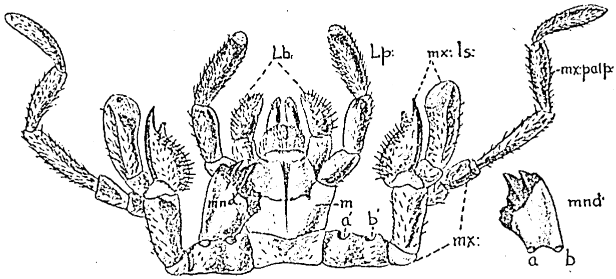

FIG. 220.—The Mouth-parts of the Common Cockroach.

mnd, Mandibles (*a b* has been removed from *a' b'*); *mx*, maxilla; *mx.ls*, maxillary lobes; *mx.palp*, maxillary palp; *m*, mentum bearing labial palp, *Lp*, and the labium, *Lb*. The central lobe of the labium, the *lingua*, can be faintly seen.

The jointed legs, borne ventrally on the thorax, are long and strong. The third and fourth joints (femur and tibia) are beset with stiff bristles, with which the body is brushed and kept clean.

The foot or tarsus is five-jointed, each joint having a velvety pad beneath it; the last also bears two claws, and between these is a special pad which may act like that on a fly's foot (p. 369), enabling the insect to run up smooth, vertical walls.

The *abdomen* is large, broad, and clearly segmented, but, owing to the varying degree to which, at different ages and in different sexes, some of these segments are retracted within others, the number to be seen in a casual external

examination varies in different specimens. It is said that ten segments actually exist.

From the sides of the last[1] segment project little tactile processes known as the "cerci anales," and in the adult males, and the young larvae of both sexes, this segment bears as well two small, slender "styles" which can be just distinguished projecting from the end of the body in the male shown in Fig. 219. The use of these is not clear.

Spiracles, for the passing in and out of air in respiration, are present laterally on some segments of both thorax and abdomen, the interchange being effected by the externally visible contractions and expansions of the latter.

Habits. Hiding all day in narrow cracks and crevices, into which its flat body can all too easily slip, it is at night that cockroaches come out in their hordes to feed on whatever animal or vegetable matter they can find, apparently eating little but tasting much.

They dislike the cold, and at the approach of winter most of them disappear, though in a warm kitchen many may remain active all the year round. Few other animals seem to like them for food, probably because of the evil-smelling fluid given out by a pair of glands on the upper side of the abdomen. The hedgehog, however, is not dainty, and will devour them in great quantities, and hence it is often introduced into a house when the insects have become a pest. Rats, cats, and frogs also occasionally eat them. Powdered borax sprinkled freely about their haunts will sometimes exterminate them.

Cockroaches breed in the summer months. The eggs are laid, sixteen at a time, enclosed in a little, reddish-brown, horny capsule (Fig. 219). This is formed within the body, and female cockroaches are often seen running about with it protruding slightly from the end of the body. It is finally deposited in some dark, sheltered crevice. The eggs lie in two rows within the capsule, and the young, when ready, push their way out at the straight, longitudinal ridge which runs along the top of it. They are very small and at first pale-coloured, but they rapidly darken, and when they are a year old, wing rudiments appear.

[1] In Fig. 219, the shading of the last segment makes it appear as if it were itself segmented, but this is not so.

Family 2: FORFICULIDAE

Type: **The Common Earwig** (*Forficula auricularia*).

Earwigs are common garden insects with a bad reputation, in spite of which they live on the whole very blameless lives, feeding chiefly on decaying vegetable matter, though they do also, to some extent, nibble the petals of a few flowers and perhaps some fruits, in attempting to get the sweet juices of which they are fond. Their reputation is further blackened owing to a superstition, for which no foundation of fact is forthcoming, that they are given to entering the ears of

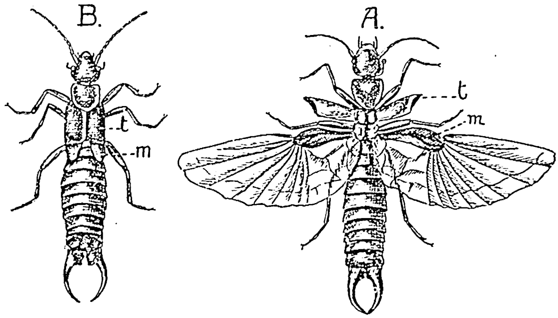

FIG. 221.—The Common Earwig (male) (*Forficula auricularia*). ×3.

B, With wings closed; *t*, tegmen or wing-cover; *m*, part of the second wing projecting beyond the tegmen; *A*, with wings widespread, showing the different parts of the second pair of wings.

people when asleep, and damaging the drum. No one as yet seems to have discovered the source of this superstition, which is found in many countries. It is suggested that the association of this insect with an ear is due to the form of the expanded wing, which is said to recall that of a human ear; but the wing is so rarely seen expanded, that this connection does not seem a very probable explanation of the name.

General Form.

Earwigs are much smaller than cockroaches, but they have a relatively longer, though narrower, body, and are always easily recognised by the curious pair of nippers or "forceps" present at the end of the body; these are longer and more sharply curved in the male than in the female, where they are straight until near

the tips. These may perhaps correspond to the "cerci anales" of cockroaches, which however are jointed—in earwigs these forceps are unjointed except in some cases where a segmentation occurs in the young before the first moult, but is lost afterwards.[1]

The *head* bears long antennae and large compound eyes, but no simple eyes, and the first segment is freely movable independently of the rest of the thorax—in all these three points the earwig resembles the cockroach. The head is, however, carried forward, instead of being bent down as in Blattidae. The *thorax* in the adult bears two pairs of wings, the hind wings being folded in a very complex way, so that they are covered when at rest by the front wing-covers (tegmina), except for two hard pieces which always project beyond them (Fig. 221, *m*). These two projecting pieces are not the tips of the second pair of wings, but merely the ends of the harder portions of these wings. The membranous part of each, which projects beyond the shaded portions in Fig. 221, *A*, are usually folded like a fan and then turned back under the harder piece, *m*. Transverse folding is also necessary to some extent, in order to get these large membranous wings packed securely away. In spite of these well-developed wings, flight seems very rare, and probably never occurs in the lives of many individuals. It is a strange fact that the wings should be so highly developed and yet should be never or rarely used.

Habits. Loving darkness, earwigs hide during the day in the spurs of flowers or any dark corner, and come out at dusk to feed. Their food is mixed, both vegetable and animal, so that, if they do harm by nibbling flower petals, they also do good by devouring harmful grubs. As has been already said, they seldom fly, but occasionally they are found after the night, stuck to some freshly tarred paling, with wings still expanded, proving that flight does, at any rate occasionally, occur. After flight, the packing away of the back wings under the wing-covers or "tegmina" is said to be aided by the action of the pincers at the end of the body, which are put into an effective position by the upward curving of the very flexible abdomen.

Eggs are laid by the female usually in the early spring.

[1] G. H. Carpenter, *Insect Transformation*.

They are deposited in a little hole in the ground, or a rotten tree-stump, and the mother watches over them day and night, and over the young larvae when first they appear. Though the females, unlike the males, can live through the winter, they die in the spring.

The young larvae are very like the adults, except for their almost white colour, the absence of wings, and the smaller number of joints to the antennae; gradually they attain the adult form, a distinct advance being manifest after each moult.

Allied Forms. The families *Mantidae* (Praying Insects) and *Phasmidae* (Leaf and Stick Insects) also belong to the Cursorial or Running Orthoptera. Of all families of insects these show the most wonderful protective coloration and mimicry of objects in their environment, and they form a fascinating study, though, as none of them are British, they must be passed over here with only a very few words.

The Stick Insect. The Stick Insect (*Carausius* (*Dixippus*) *morosus*), though not British, is very frequently to be obtained here, and is an interesting object for study, and easy to keep, since it merely wants a few leaves of privet on which to feed. The emergence of the fragile thread of a creature from the little egg, its development into the wingless adult with its brown, stick-like body, the rhythmical swaying of its body from side to side when at peace with the world, its alternation between death-like passivity, with all its legs stretched out in a line with its body, and surprising activity, with legs outstretched on either side, its varying protective coloration, the alleged parthenogenesis of the eggs —all these things make it an interesting pet to keep.

Sub-order 2: Saltatoria (The Jumping Orthoptera).

Besides those Orthoptera which progress over the ground by running, like the Earwig and Cockroach (Cursorial forms), there is a large number specially modified for jumping (Saltatorial forms). To this sub-order belong Grasshoppers, Locusts, and Crickets.

In all these forms the body is laterally compressed, and the hind legs are exceptionally strongly developed, since it is

by means of them that the insects leap over the ground; also, most of them "chirp," producing the sound with a special musical instrument formed by the wing-covers and the third joints of the hind legs (see below).

Family 1: Acridiidae (The Common or Short-horned Grasshoppers)

The small Grasshoppers common amongst our grass during the summer, which are so frequently to be heard and seen, but are so very difficult to catch because of their extreme agility, belong probably to one of the only three common British genera of short-horned Grasshoppers.

Genus *Stenobothrus* has delicate, tapering antennae.
,, *Gomphocerus* has club-shaped antennae.
,, *Tettix* is peculiar because of the extension of the first thoracic segment backward over the abdomen. It is common amongst dead leaves.

All three genera are vegetable feeders only, and the female lays her eggs in a little hole which she excavates in the soil.

The *musical organ* with which the grasshopper chirps consists of a row of little bead-like projections on that side of the femur next the body; with these the grasshopper rubs a prominent ridge on the outer edge of the upper wing, thus throwing the wing into vibration and causing a musical note. Only the males have this organ well developed, but it is present in the females in a rudimentary condition. It is known usually as the organ of "stridulation."

An *auditory organ*, by which it is probable these sounds are received, is present in the first segment of the abdomen, lying just above the union of the hind leg and the thorax. It consists of a little membrane or drum, surrounded more or less by a definite rim or overhanging flap of the thoracic wall, and supplied with a nerve, nerve-ganglion, and muscles, as well as with special tracheae. These "ears" are present in both male and female, and are found even in many species that do not produce any sound audible to the human ear — but possibly grasshoppers are sensitive to sounds which do not affect us.

The term *Locust* is one applied popularly to any kind of grasshopper which occasionally multiplies with great rapidity,

so that their offspring necessarily migrate in large numbers to new pastures for food. Such locust swarms do not now occur in Britain, but in some countries they are still a very serious scourge, devouring as they migrate all the vegetation over which they pass.

Family 2: LOCUSTIDAE (THE LONG-HORNED GRASSHOPPERS)

The Locustidae differ from the ordinary grasshoppers in having long, delicate antennae and a four-jointed instead of

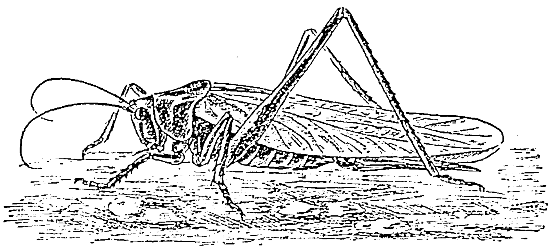

FIG. 222.—*Locusta viridissima*, the Green Grasshopper. (Life size.)

a three-jointed tarsus, also in the "chirp" being produced merely by rubbing together the roughened edges of the wing-covers. The auditory organs are here placed on the fourth joint of the first pair of legs, and are present in both sexes.

None of this family go for the long flights characteristic of the so-called "locusts" of the Common Grasshopper tribe.

The Green Grasshopper (*Locusta viridissima*) is fairly common in Britain, but is rarely seen, as it is active chiefly at night, when it chirps loudly, on a shrill, not unpleasant, note, sometimes for a quarter of an hour without stopping. It is an insect-eater, devouring cockchafers or crickets with avidity; but it also likes an occasional sip of fruit juice.

The North American *Katydids* belong to this family.

Family 3: GRYLLIDAE (CRICKETS)

Crickets resemble, in most of their characteristics, the Long-horned Grasshoppers, though their tarsi are usually

three-jointed only. They differ also in the way in which the tegmina lie flat, with the outer margin bent over the side of the body.

The House Cricket, or "Cricket on the Hearth" (*Gryllus domesticus*), which used to be fairly common, has now become much rarer.

The Mole Cricket (*Gryllotalpa vulgaris*) is also rare in England, though common in South Europe. It is of special interest because of its adaptation to an underground life, living in burrows which it excavates for itself with its much-modified front legs.

Classification of the Orthoptera mentioned in Chapter XIX.

Sub-order 1.—**Cursoria.** Those which run along the ground, the hind legs being very similar to the others.

Family 1. Blattidae. Cockroaches (*Blatta*).
,, 2. Forficulidae. Earwigs (*Forficula*).[1]
,, 3. Mantidae. Praying Insects (*Mantis*).
,, 4. Phasmidae. Leaf Insect (*Phyllium*).
Stick Insect (*Carausius*).

Sub-order 2.—**Saltatoria.** Those in which the hind legs are much bigger and stronger than the others, being adapted for leaping.

Family 1. Acridiidae. Common Short-horned Grasshoppers (*Stenobothrus*, *Gomphocerus*, *Tettix*).
,, 2. Locustidae. The Long-horned Grasshoppers.
,, 3. Gryllidae. House Crickets (*Gryllus*).
Mole Crickets (*Gryllotalpa*).

Practical Notes

1. The *Cockroach* is the insect most generally used, in a practical zoology course, as an introduction to the typical structure, both external and internal, of an insect, and full directions for its dissection are given in almost any practical zoology book. Here, therefore, it is sufficient to suggest that living specimens be captured, and their external form and habits studied, the points mentioned in the previous chapter being carefully verified. To kill a cockroach for more detailed study, drop it into boiling water ; this causes death instantaneously. The mouth-parts and segments of the body can then be examined, and the spiracles down each side

[1] See footnote, p. 299.

of the body detected. There are ten pairs of these altogether, the largest being those on the second and third thoracic segments.

2. *Earwigs*, *Grasshoppers*, etc., should be looked for out-of-doors and their habits studied. If kept in captivity care must be taken to keep their home damp. For suitable sub-terraria see Appendices D and E.

3. A visit may be made to a museum where there is an exhibit of *Leaf* and *Stick Insects*, and their curious adaptations noted. These observations should be used in a more general study of "Protective Coloration and Mimicry in Insects."

4. Read one or more of the following books: *Animal Coloration*, by F. E. Beddard; *The Colours of Animals*, by E. B. Poulton; *Concealing Coloration in the Animal Kingdom*, by G. H. Thayer.

CHAPTER XX

INSECTA (*continued*)

Order: Rhyncota or Hemiptera (Bugs, etc.)

The various species of bugs form an order of Insects to which two separate names have been applied, each of which has reference to a different special characteristic found in its members.

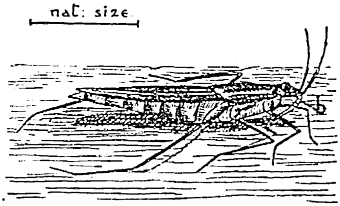

Fig. 223.—The Pond Skater (*Gerris*), on the Surface of the Water.

b, Rostrum or beak.

The name *Rhyncota* (*rhynchos*, a beak or snout) refers to the peculiar rostrum or beak which, when not in use, is bent under the body, and therefore cannot be seen except from below or in a side-view, as in Fig. 223. This beak in some forms is half as long as the body. It is a sheathing structure formed from the upper and lower lips (labrum and labium), and it encloses four bristle-like lancets, two of which are, however, frequently fused together. These lancets probably correspond to the fused maxillae and the mandibles of other insects.

The name *Hemiptera* (*hemi*, half; *pteron*, a wing) refers to a characteristic of the first of the two pairs of wings, the outer halves of the two front wings being membranous, whilst the basal halves are firmer and form wing-covers, resembling those of beetles. This characteristic is not, however, constant throughout the order; it is, moreover, conveniently taken as the basis of a subdivision of the order, and hence the name Rhyncota seems a better one for the entire group.

In all members of this order the metamorphosis is gradual. The larva has a proboscis like that of the adult, but is wingless. There is no quiescent pupa, the wings developing gradually.

Sub-orders. The order is subdivided according to the structure of the wings. The larger Water-bugs are the best known of the sub-order *Heteroptera*; in them the basal portions of the fore-wings are horny, and the tips of these wings, as well as the whole of the second pair, are membranous. The wings fold flat on the back when at rest. The beak or "rostrum" is attached well forward.

The second sub-order, the *Homoptera*, consists of forms in which the two pairs of wings are alike and both membranous, and are held vertical or inclined when at rest; the rostrum is placed on a level with the bases of the fore-legs. This sub-order includes the well-known garden pests, the Green-fly (*Aphis*), and also the interesting Bark-lice (*Chermes*).

Sub-order 1: Heteroptera or Water-bugs.

Series A. Aquatic forms living under water, and with the antennae hidden on the under side of the head.

Type: The Water Scorpion (*Nepa cinerea*).

The Water Scorpion is a form nearly always to be found in any shallow piece of stagnant water. It is easily recognised by its curious, flattened, dark-brownish body, which looks rather like a fragment of a decaying leaf, and is often difficult to detect, whether it is resting on the water surface amongst the floating vegetation, or lying in wait for its prey on the dark mud bottom of a pond. The difficulty of seeing it is further increased by its extreme immobility—it rarely moves, and then but slowly. The wings are pressed flat on the body, and are seldom used (Fig. 224).

Food. To catch its food, which consists of small insect larvae or of tadpoles, it uses its front pair of legs, which project forward so that the last joints are brought to the level of the mouth, where they spread out on either side. These last joints are peculiar, for the sharply pointed and sharp-edged tarsus can be closed into the deep groove of the preceding joint, like the blade of a clasp-knife into its handle;

these "knives" can be swiftly whisked open, and the prey caught with them and held, whilst the sharply pointed, short beak is rapidly put into action to suck up all the nutritive juices of the victim.

Respiration. At the end of the body are two grooved, hair-like projections, generally held together so that they look like one (Fig. 224, *A*). The tube thus formed is at times pushed upwards through the surface film of the water into the air above, and through it air is drawn down into the two spiracles situated at the tip of the abdomen. Owing, however, to its sluggish life, *Nepa* only occasionally needs to come to the surface for a fresh supply of air.

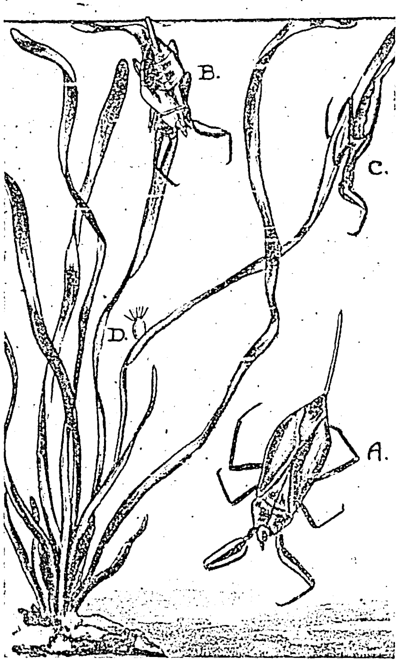

FIG. 224.—The Water Scorpion. (*Nepa cinerea.*) (Natural size.)

A, Full-grown insect swimming; *C*, another waiting for its prey; *B*, a larva breathing at the surface; *D*, a single egg resting on a leaf.

Reproduction. Eggs are laid in the water during the summer; each is a small white oval body with seven little hairs projecting at one end. In the oviduct these eggs are in strings, each circle of hairs forming a cup into which the next egg fits; as each egg is discharged, however, the hairs become recurved;[1] a single egg may be found adhering to a submerged water-weed (Fig. 224, *D*). The function of the hairs may possibly be to retain a supply of air for the developing egg.[2]

[1] See *The Classification of Insects*, by J. O. Westward (1840).

[2] *Cambridge Natural History*, vol. vi. p. 564.

The Larva. The larva is very like the adult, though with a rather thicker body, and with only a short process at the end of the abdomen instead of the delicate, long respiratory tube of the adult (Fig. 224, *B*). The wing rudiments appear at first as little thickenings on both sides of the thorax, but they increase in size and definiteness at each moult.

The Water Stick Insect (*Ranatra*).

Closely allied to the Water Scorpion is the Water Stick Insect or Stick Scorpion (*Ranatra linearis*). It is found in ponds in the south of England, though it is somewhat rare.

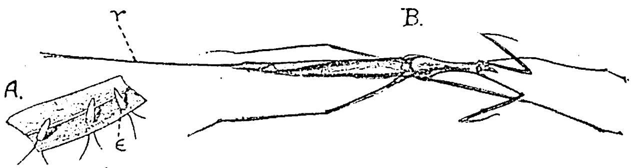

FIG. 225.—The Water Stick Insect (*Ranatra linearis*).
A, Eggs, *e*, inserted through a leaf; *B*, adult insect; *r*, respiratory tube. (Natural size.)

Its body is long, narrow, and cylindrical, and looks like a tiny dry stick. It has the same adaptation of the front legs for catching its prey as the Water Scorpion, and the same respiratory tube at the end of the body. It is a more active hunter than *Nepa*, and it more frequently leaves the water and takes to flight.

The eggs of this insect are laid separately, inserted usually in the floating stems or leaves of water plants; each egg has two projecting hairs (Fig. 225).

The Water Boatman (*Notonecta*).

The only British Water Boatman (*Notonecta glauca*) is to be found in most ponds, and is a very dangerous enemy to many of the other inhabitants. These "Boatmen" are well known from their habit of swimming on their backs, rowing themselves swiftly along by the vigorous strokes of their powerful hind legs. The last segments of these legs

are fringed with stiff hairs (Fig. 226), which are depressed at the end of each stroke. The body is long and narrow, the ventral surface flat, and the back strongly keeled, giving it a superficial resemblance to a boat, though the body is blunt in front and pointed behind. The colour is a pretty bluish-grey with some black on the back. The first segment of the thorax is very highly polished, and the glossy triangular plate of the second segment (the "scutellum") is also large and conspicuous, as is usually the case in Rhyncota. The *wings* are

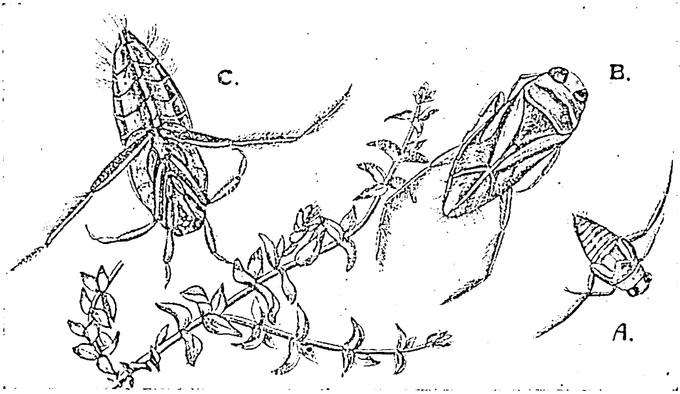

FIG. 226.—The Water Boatman (*Notonecta glauca*).
A, Larva swimming; *B*, back view of an adult *Notonecta*; *C*, ventral view. (×1¾.)

well developed, and the insect often flies in the evening with a strong, swift motion and a humming sound. When at rest, the horny base of the fore wing covers its membranous portion and also the very delicate second pair of wings. The under surface of the body, *i.e.* the side which floats uppermost, is covered with small hairs, and glistens like silver in the water owing to the air which is entangled amongst the hairs. This film of air keeps the body, even when submerged in the water, completely dry, and also makes it buoyant, so that, when at rest, it floats to the surface with the tail projecting, and opens up fresh communication with the atmosphere. The air-film over the body and below the wings is thus renewed, and fresh air is taken in by the spiracles, which lie just below the outer horny edge of each front wing. In

order to remain below the water without moving, the insect holds on to the weeds by the short first pair of legs, and the hind legs lie stretched out at full length on each side. It is a swift swimmer, and will catch animals larger than itself, diving underneath its victim and catching hold of it with its front legs, and then burying its powerful beak in the flesh and sucking from it all its juices. The *eggs* are laid singly in the tissues of water-weeds. The larvae (Fig. 226, *A*) are in shape and habits much like the adults, but are of a pale-green colour with red eyes; also they have at first no wings, though these develop gradually.

Corixa.

The closely allied, but much smaller, *Corixa* (Fig. 227) uses its back legs in swimming, much as *Notonecta* does, but swims with its back uppermost; also the back is flat instead of being strongly keeled, and the "scutellum" is not distinct as it is in the "Boatman." The body, which is about half an inch long, is heavier than the water, and therefore *Corixa* has to *swim* to the surface to breathe, instead of merely floating up. At the surface, the thorax projects out of the water, and air is taken in directly by the thoracic spiracles, a new air-film forming round the neck.

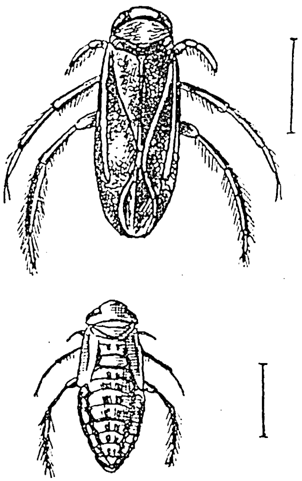

FIG. 227.—*Corixa geoffroyi.* The adult insect above and the larva below. (Natural size shown by the lines to the right.)

The commonest species is *Corixa geoffroyi*, which is dark brown in colour, and spotted with yellow on the thorax and upper wings. The *eggs* are fixed to submerged objects, and the larvae are similar to the adults except for their lack of wings. *Corixa*, like *Notonecta* and *Nepa*, spends the winter buried in the mud at the bottom of the water, but a warm day will always entice it out for a swim and a feed.

All the four genera of Heteroptera so far mentioned have been alike in living a submerged life, and in having small and concealed antennae. Those now to be described (*Hydrometra*, *Gerris*, and *Velia*) all have long and conspicuous antennae, and they live on the surface of the water, running or jumping actively over the surface film, though occasionally penetrating it to dive below.

Series B. Forms living on the surface of the water and having conspicuous, long antennae; also all the terrestrial Heteroptera.[1]

The Pond-skater (*Gerris*).

The little narrow-bodied, long-legged Pond-skaters are very numerous on the water surface, over which they slide, or sometimes progress in a series of leaps. Occasionally they dive below the surface, when the hairy body is seen to have a silvery air-film covering it. The four-jointed antennae are so long as to look almost like an extra pair of legs. The first pair of legs are held forwards and used for prehension. By the lengthening of the first segment of the thorax, this pair is widely separated from the second pair, which is that chiefly used in locomotion, the hind pair serving to guide the movements. As in all water-bugs, this genus has a long beak with which the food is pierced and its juices extracted (see Fig. 223). It feeds very largely on dead and dying insects that fall on to the surface of the water.

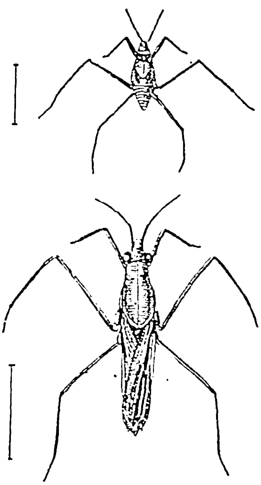

FIG. 228.—The Pond-skater (*Gerris*).

Larva above, adult below—winged variety. (Real length shown by the lines to the left.)

The adult insects are not all alike. Some have only short wings, and are incapable of flight, whilst others have well-developed upper horny wings and lower membranous ones with which they can fly.

[1] For an account of the most notorious of these, the Bed-bug (*Cimex*), see British Museum *Economic Pamphlet*, No. 5, price 2d.

The *eggs* are laid in a small mass of mucilage on some submerged water-plant, and the larvae are often to be found submerged, though as a rule they skate on the surface with their parents.

The Water Cricket (*Velia currens*).

The Water Cricket is very similar to the Pond-skater in appearance and habits, but the first and second pairs of legs are not separated by such a wide interval, the thorax being relatively shorter. Further, it very rarely develops wings at all, and the body is marked by two orange stripes down the back.

Water Crickets are all very active and good climbers, hence if they are kept in an aquarium it must be covered. Though living mainly on the surface, they enter the water much more readily than *Gerris*.

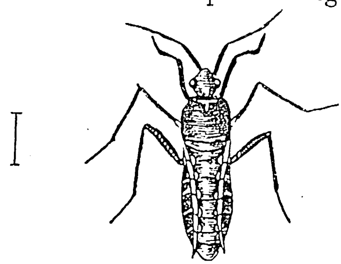

FIG. 229.—The Water Cricket (*Velia currens*).
(Real length shown by the line on the left.)

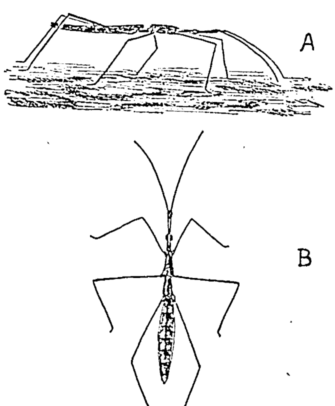

FIG. 230.—The Water Gnat (*Hydrometra stagnorum*).
A, Side view. *B*, Dorsal view. (×2.)

The Water Gnat (*Hydrometra stagnorum*).

The Water Gnat, or Water Measurer, is peculiar because of the great elongation of the head, and the very narrow, dark-coloured, stick-like body and long, very slender legs; it is about half an inch long and half a line broad. Wings are never developed, and the insect lives a quiet life walking about on the water surface or on the grasses by the waterside. It never enters the water.

Sub-order 2: Homoptera (Green-fly, Bark-lice, etc.).

In all this division of the Rhyncota, the consistency of the front wings is the same throughout, and, in many, all four wings are membranous and transparent. They cover the body in a roof-like manner, the two pairs sloping upwards towards each other, so that their inner margins touch along a median longitudinal line. The front of the head is bent over so that it faces downwards and backwards.

In the Scale Insect and Cicada there is a resting larval stage in which the wing rudiments grow out beneath the loosened larval skin, a stage which prefigures the true pupal stage of higher insects.

Family 1: Aphidae

Type: Green-fly (*Aphis*).

These insects are only too well known superficially, and the name "Green-fly" brings up a mental picture of clusters of the minute, wingless, soft, green creatures, on our rose-buds or daisy heads, covering the under surface of sycamore leaves, or infesting many another plant, feeding on the juices of young shoots and leaves, and doing an enormous amount of damage.

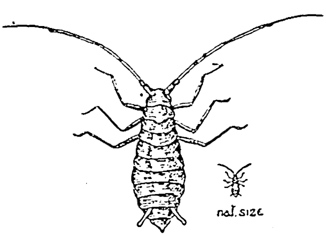

FIG. 231.—An Aphis off Sycamore. (Wingless form.)

There are many different kinds of Green-fly, varying in colour, size, and habits, but all having smooth, plump, segmented bodies, a head provided with two long, dark antennae, a pair of compound eyes, and mouth-parts as in the Heteroptera, but here the sucking-tube, when not in use, is pressed against the under side of the thorax. The thorax has three pairs of long, thin legs, but in the majority of cases is wingless; in the autumn, however, many winged forms appear. The abdomen in many species bears on the fifth abdominal segment a pair of short tubes which project upwards and secrete an oily juice, often to be seen as a shining drop at the end of each tube. This substance used to be looked upon as the "honey-

dew" which is eaten by ants; it is, however, waxy in nature and not sweet, and the real "honey-dew" is a secretion which is given out copiously from the end of the alimentary canal, often making sticky the whole leaf inhabited by the *Aphides*, or even falling in little drops to the ground below. This is often to be noticed on the pavements of a town below sycamore and lime trees which are infested with Green-fly.

For the sake of this sweet juice, *Aphides* are visited and often protected by ants, different species of ants being associated with different species of *Aphides*. The black garden-ant seems to visit chiefly the *Aphis* of the rose-tree, or some other shoot-sucking green-fly, whilst the small yellow ant gets its honey-dew from certain subterranean root-sucking *Aphides* (see pp. 452-3).

The juices of the plant are sucked up by the *Aphis* by means of a proboscis similar to that in all Rhyncota (p. 310), and this results in serious injury to the plant; for though individually each *Aphis* is insignificant, they often occur in such numbers that they seriously menace the life of a plant.

Multiplication. The rapidity with which they multiply is astounding. It has been calculated that a single *Aphis* would, if unchecked, in two or three years produce so many millions of descendants that, owing to their ravages, there would be left in the world none of the plants on which they are accustomed to feed. They are, however, kept in check not only by such means as heavy rain, and sudden changes in the temperature of the air, to which they are very sensitive, but also by the fact that many other insects feed on them.

The method by which their unusually rapid multiplication is brought about is immediately obvious if we study the course of the life-history of one *Aphis* from the egg stage.

Life-history. An egg which is laid on the plant in the autumn hatches out in the spring as a wingless form, which at once pushes its proboscis into the plant tissues and begins to feed, very soon giving forth from the end of its body minute, living Green-fly, at the rate of two or more a day. These young ones, in their turn, begin to reproduce in the same way in a very short time, warm dry weather favouring rapid production. All through the summer an enormous number of young is produced thus, partheno-

genetically (*i.e.* without any fertilisation of an egg having taken place). Most of these are wingless like the parent form, but a small and varying proportion of winged parthenogenetic females is also produced. The production of these winged individuals seems to be correlated with the amount of food supply. When this is running short, owing to the large number of wingless individuals produced, then winged forms appear, which migrate to a fresh plant and there found a new colony.

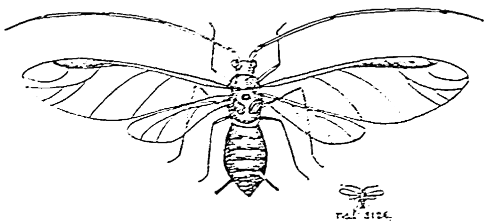

FIG. 232.—Aphis off Sycamore. (Winged form.)

Young are produced by these winged forms also parthenogenetically, and they closely resemble their parent. The wings of any winged individuals grow gradually with the successive moults of the skin. In some cases these winged individuals go through their gradual development protected by a delicate web of silk threads stretched across part of the leaf.

In the autumn, however, there always appear normally sexual individuals. The *females* are always wingless, and usually smaller than the members of the previous summer broods. The *males* are usually winged, though wingless males do occur.

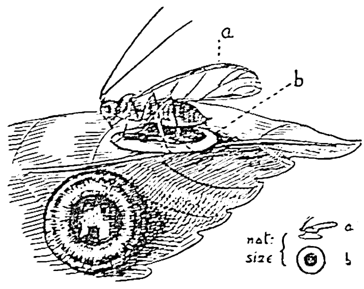

FIG. 233.

a, A dead Aphis that has been attacked by the hymenopterous parasite *Praon*, one of the false Ichneumon-flies; *b*, disc woven of silk threads concealing the larva of *Praon* which has now left the body of the Aphis. Lower on the leaf a disc is shown in surface view.

The fertilised eggs are laid amongst the scales of the buds of the plant on which the *Aphis* feeds, and these eggs are able to endure the cold of winter which kills the adult insects. They hatch in the spring, and so start the race afresh.

Aphis Parasite. Sometimes in the autumn, under sycamore, lime, or fern leaves, the dead outer skin of a winged Aphis may be found fixed on to a light-brown disc formed of interwoven silken threads (see Fig. 233, *b*). Within this disc may be seen moving a little legless grub which seems to be the grub of a parasite (one of the Braconid Ichneumon-flies, called *Praon*) that has lived within the body of the Aphis for a time, and then eaten its way out, killing the Aphis, and protecting itself by the silk-woven disc. Among the other enemies of Aphides are the Ladybird (pp. 280-1), the Hover Fly grub (p. 371), and the larva of the Lacewing Fly (p. 356), each of which accounts for a prodigious number of Green-fly. The Blue-tit also is a good friend to the gardener in this respect.

The Woolly Aphis. There are many kinds of Aphides inhabiting different plants. The Bean Aphis or Black Blight, the Plum Aphis, and the Pea Aphis are all very destructive, also the "Woolly" Aphis, the young of which live on the branches and on the roots of apple and pear trees, forming round themselves masses of a white woolly substance excreted by certain glands in their backs. The flies themselves are a purplish-brown colour, except for the wingless egg-laying females, which are reddish-yellow and very small, not usually more than $\frac{3}{1000}$ of an inch long. These curious females and wingless males are to be found in the autumn. One egg is laid and then the female dies. This sexual reproduction only takes place rarely. During those years that it is absent, the race is carried on from year to year by the hibernating parthenogenetic females. The Woolly Aphis has no secreting tubes projecting from the abdomen.

The various common Aphides do not cause any gall to form on the plants on which they feed, but the closely allied genus *Chermes* causes the production of the well-known "False Cone Galls" on the spruce fir (Fig. 234).

Bark-lice (*Chermes*).

The life-history of this form is extraordinarily complex. It is given here as an example of the curious phenomenon of the same insect passing different definite stages of its life on

different plants in a regular cycle of generations. It will be perhaps simplest to start at the stage in which the *Chermes* insect passes the winter on the spruce fir—the stage known as *Chermes abietis*.

Generation I. On Spruce.

If spruce twigs are examined in November, there may be seen on some of the terminal clusters of buds, especially in the crevices between the buds, little white waxy patches (Fig. 234, *h*). If some of these are

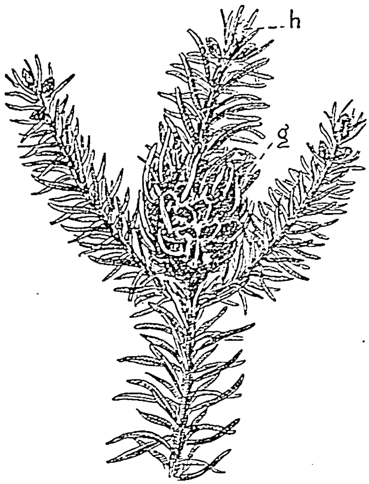

FIG. 234.—Spruce twig infected by *Chermes abietis*.

h, Waxy patch covering hibernating *Chermes* insects; *g*, gall formed by such insects when they awake to activity after the winter sleep.

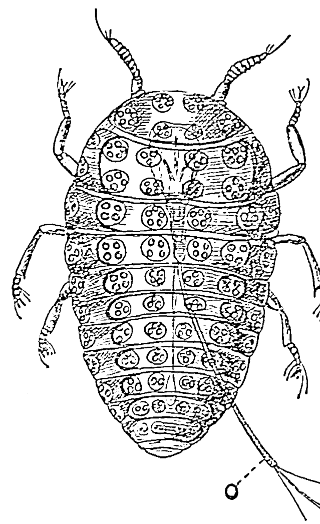

FIG. 235.—*Chermes abietis*. (Much enlarged.)

(Obtained from the waxy patch shown in Fig. 234 and made transparent as explained in the text.) *o*, Rostrum.

scraped off, put on a slide, and treated with turpentine, the wax dissolves away, leaving exposed a number of little wingless *Chermes* insects, which were just entering on their long hibernation protected by the wax. When mounted in glycerine, slight pressure on the cover-slip causes the contents of the body to stream out, and the transparent skin is left as in Fig. 235, showing clearly the regular arrangement of the little perforated shields, from which, according to Professor

Miall,[1] exude the waxy threads which covered the body; the curious, long, three-jointed proboscis or "rostrum," which lies along the body ventrally when at rest, also becomes obvious, and projecting from it may be seen the three long, fine lancets found in all Rhyncota (p. 310). Here they are unusually long, and their function at this time of year seems to be to fix the insect firmly to the spot where it hibernates, and hence they are described by Buckton as "spring cables."[2] The antennae of *Chermes* are short compared with those of an *Aphis*. These hibernating forms on the spruce are all female insects. In the spring they awake to activity, and begin to pierce the young, growing tissues at the base of the bud and suck nourishment from them. These punctures cause the formation of such a gall as shown in Fig. 234, *g*; the tissues swell up and form a little green structure which is at first rather like a young cone with scales arranged regularly on it and with little cavities lying below the scales.

Generation II. Still on Spruce.

As soon as the female insect responsible for this gall has fed sufficiently on the juices of the bud, she lays a little cluster of parthenogenetic, stalked eggs, and then dies. The larvae which hatch from these eggs make their way into the cavities of the gall, and remain there feeding on its tissue, gradually acquiring their adult, winged condition. In August, usually, the perfect insects creep out of the gall, which is now brown and woody, and the scales of which have separated, exposing the cavities (Fig. 234, *g*). The winged forms which come out are again all females, and they now act in one of the two following ways:

Generation III. On Spruce and Larch.

(1) Some of them stay on the spruce and lay parthenogenetic eggs which form fresh hibernating females of *Chermes abietis*;

(2) Some migrate to the larch and there lay clusters of stalked eggs (Fig. 236, *A* and *B*), which give rise to female insects that hibernate on the larch, and are known as *Chermes laricis* (Fig. 236, *C*).

Generation IV. On Larch. Chermes laricis.

This hibernating female awakes in March, and lays parthenogenetic eggs on the larch twig, which by May have developed into both wingless and winged female forms.

[1] *Injurious and Useful Insects*, by Professor Miall, 1902.
[2] Monograph on *British Aphides*, by Buckton, vol. iv., Ray Society.

Generation V. Male and Female. On Spruce. The winged forms return to the spruce and lay parthenogenetic eggs there in the summer, and these produce both female and male insects—the first appearance of males in the life-history.

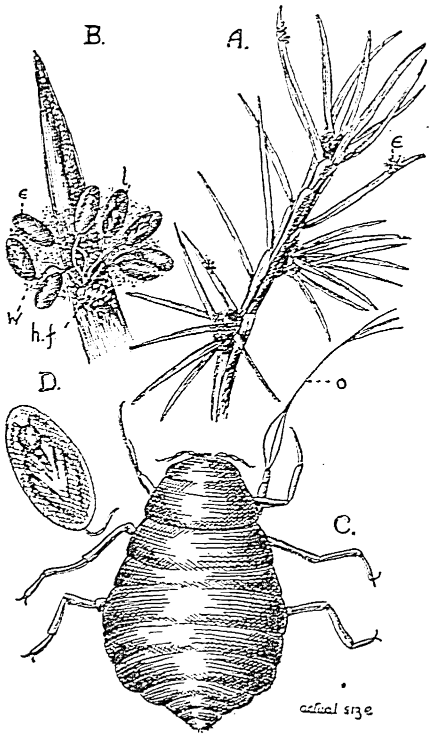

FIG. 236.

A, Larch infested by *Chermes*; *e*, cluster of stalked eggs; *B*, cluster of eggs enlarged, showing wax (*w*) surrounding them; *h.f.*, hibernating mother; *l* is an egg in which the new individual is almost developed; *D*, view of *l* enlarged; *C*, hibernating female on larch, much enlarged (actual size is less than a pin's head).

Generation VI. or I. On Spruce. Finally, each of these females lays one fertilised egg on the spruce in the autumn, which may develop into such a hibernating female as was described as Generation I

Perhaps this very complicated life-history can be made clearer by the following tabular summary.

Summary of Generations of Chermes

	On Spruce.	On Larch
1st Generation	Hibernating wingless females which form *galls* in the spring and lay eggs.	
2nd Generation	*Winged females*, leaving galls in August.	
	Some stay on spruce and lay eggs in autumn.	Some migrate to larch and lay eggs there in autumn.
3rd Generation	Hibernating females, *like Generation I.*	Hibernating females which lay eggs on larch in spring.
4th Generation	*Winged forms* returning to spruce and laying eggs there in August.	Wingless forms.
5th Generation	Winged female and male. Eggs fertilised.	
6th Generation	Hibernating females, wingless, *like Generation I.*	

We find, therefore, on the spruce from October to December hibernating females of two kinds :—

(1) Those arising from the parthenogenetic eggs of the *Chermes abietis* which has never left its spruce home;

(2) Those arising from the fertilised egg laid on the spruce. These are the fourth generation from that *Chermes abietis* which migrated from spruce to larch in the August of the previous year, and whose second generation of descendants returned to the spruce in the summer of the second year in the cycle under consideration.

This insect *Chermes* is very undesirable in spruce and larch plantations, not only because of the harm done by it to the trees in drawing nourishment from them and causing distortion of the branches, but also because it is thought that when piercing the tissues the insect often inoculates them with the spores of a fungus (a Peziza) which causes the disease known as Larch Canker.[1]

A.

B.

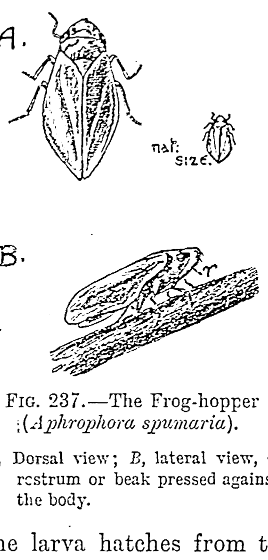

FIG. 237.—The Frog-hopper (*Aphrophora spumaria*).

A, Dorsal view; *B*, lateral view, *r*, rostrum or beak pressed against the body.

Family 2: CERCOPIDAE (FROG-HOPPERS)

The insects which cause the accumulation of frothy substance on many plants known as "cuckoo-spit" or "frog-spit" are the Frog-hoppers which form the family *Cercopidae* of the Homoptera. The froth is formed by the little yellow and green, or brown, six-legged larvae who live within it, and only leave it on becoming winged adults. When the larva hatches from the egg it is naked; it at once proceeds to pierce the stem of the plant on which it finds itself, and sucks up the sweet juice; then, as a result of the digestion of this, a clear, watery, slightly viscid sap exudes from the end of its body and covers it and fills all the space between it and the stem; also two little glands at the end of the body secrete a waxy substance which, with the sap, makes a kind of soapy solution, into which it proceeds to blow bubbles of air until it

[1] This fungus, *Dasyscypha calycina*, causes little yellow discs, about $\frac{1}{10}$ of an inch across, on the larch stems.

has made a little frothy soap-bubble home all round itself; within this it lives protected from danger of drying up in the heat of the sun, and from the attacks of enemies. It is interesting to watch the little larva tip up the end of his abdomen into the air and, grasping a bubble of air with two little processes on the end segment, turn this down again into the soapy fluid and set it free, doing this some seventy or eighty times till the whole mass is filled with bubbles. The full-grown insects have earned the name of Frog-hopper from the surprisingly big leaps they are able to make.

Family 3 : Coccidae (the Scale Insects)

Scale Insects are minute, degenerate forms which live closely adhering to the bark, fruit, or leaves of a tree, usually hidden by a little scale—rather like one valve of a minute mussel shell—formed by an excretion from the body of the insect which shelters below it, as *e.g.* in the Mussel Scale Insect of the apple tree (Fig. 238). In some forms, the scale is replaced by a powdery mass, when the creatures are known as "mealy-bugs." The full-grown insect is very degenerate, but the larva is more active, and does much damage to the plants on which it feeds.[1] The Mussel Scale Insect is common on apple trees.

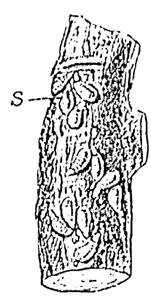

Fig. 238.—Scale Insects on Apple Tree (*Mytilaspis pomorum*). *s*, Scale covering one individual (nat. size).

Family 4 : Cicadidae (Cicadas).

Although this family has only one British species and that a very rare one, it is just mentioned here because of the notoriety gained by its male members of being the noisiest of all insects—the females are entirely silent. The shrill, screeching chirp of the male Cicada far exceeds in sound that of the grasshopper or cricket (see pp. 306-7). The noise is made by the vibration of little membranes stretched by the side of the spiracles and set in motion by the passage of the air from the

[1] For an account of this form see *Injurious and Useful Insects*, by Professor Miall.

tracheae, and these form a very complex little voice-organ. The creature is common in S. Europe and in all the warmer regions of the earth.[1] The North American species *Cicada Septendecim* is notable in another way, for it actually lives *seventeen years* underground before it comes to the surface for its brief, noisy, aerial life, when it mates and lays its eggs in incisions in the stems of plants; the larvae, as soon as they hatch, burrow into the ground.

Sub-order 3: Anoplura.

This sub-order consists of the small wingless forms, known as Lice, which are parasitic on mammals, sucking their blood by means of a peculiar hooked tube on the head. *Pediculus* is the Louse which attacks man.[2]

Classification of the Rhyncota mentioned in Chapter XX.

Order. RHYNCOTA or HEMIPTERA (BUGS).

Sub-order 1. **Heteroptera.**

Series A. Aquatic forms with small, hidden antennae.

Genus 1. *Nepa*, the Water Scorpion.

„ 2. *Ranatra*, the Water Stick Insect.

„ 3. *Notonecta*, the Water Boatman.

„ 4. *Corixa*.

Series B. Forms with long antennae, living on the surface of water or on land or parasitic.

Genus 1. *Gerris*, the Pond-skater.

„ 2. *Velia*, the Water Cricket.

„ 3. *Hydrometra*, the Water Measurer or Water Gnat.

„ 4. *Cimex*, the Bed-bug.

Sub-order 2. **Homoptera.**

Family 1. Aphidae. Green-fly and Bark-lice.

„ 2. Cercopidae. Frog-hoppers.

„ 3. Coccidae. Scale insects.

„ 4. Cicadidae. Cicadas.

Sub-order 3. **Anoplura.**

Genus *Pediculus*, the Louse.

[1] For full account see *Social Life in the Insect World*, J. H. Fabre.

[2] See British Museum *Economic Pamphlet*, No. 2, price 6d.

Practical Notes on Rhyncota

1. Collect from a pond with a dipping-net any of the water-bugs mentioned in this chapter. Examine them carefully and keep some for a few days. Remember nearly all are carnivorous, and therefore must be kept alone and fed on special animal food.[1]

2. Find Green-fly in any garden, and work out its life-history. Isolate one insect and determine its rate of multiplication. Try to distinguish the different kinds of Aphides, making use of such books as Professor Miall's *Injurious and Useful Insects*, and also the monograph on Aphides, by Buckton, in vol. iv. of the Ray Society Publications.

3. Search spruce and larch trees in the autumn for hibernating female *Chermes*, and for the cluster of eggs. Try to work out their complicated life-history, protecting a twig, where eggs have been found, with a muslin bag, and visiting at intervals during the following ten months to note what changes have occurred.

Refer to *Forest Entomology*, by Gillander, for further details, also to the *Cambridge Natural History*, vol. vi. p. 586.

4. Examine apple and other fruit trees for the Mussel Scale Insect, and with a strong magnifying lens try to make out its structure and life-history.

Refer for further details to the *First Report on Economic Zoology*, by F. V. Theobald.

5. Remove a Frog-hopper larva from its frothy home, and having studied its structure, place it on a fresh stem and watch it at work making a new protective froth.

[1] For identification of specimens see *Hemiptera Heteroptera*, by E. Saunders (1892).

CHAPTER XXI

INSECTA (*continued*)

Order: ODONATA (DRAGON-FLIES)

THIS family of the Dragon-flies is a very ancient one; fossil dragon-flies occur plentifully in the lower Liassic rocks in the West of England and elsewhere. Before birds or even flying reptiles appeared on the earth, the air was the domain of insects, some of them very large, and a dragon-fly with a wing expanse of twenty-seven inches has been found in the coal measures of the Palaeozoic rocks. The largest known living dragon-fly, an American species, is not six inches across. The aquatic larvae are carnivorous, and have a curious modification of the lower lip for catching their prey. The perfect insects are also carnivorous; they have very small, inconspicuous antennae; the segments of the thorax are much thickened vertically, and slope from below backwards, so that the legs are always attached in front of the wings. The wings are usually transparent, and have a very complex network of nervures which differs in certain points in the different families; in all of them the front margin of each wing has, near the middle, a slight irregularity, looking as if it had been broken at this point; this is called the "node" of the wing. There is a long abdomen with "cerci" or anal appendages.

Type: **The Blue Dragon-fly** (*Aeschna cyanea*).

Aeschna is one of the largest and most striking British Dragon-flies, frequently to be seen flying with swift, powerful drats by the side of streams and ponds, and even in gardens,

far from any water, flying right over the tree tops when alarmed.

General Form and Colour. The winged insect has a long, tapering body and large wings (Fig. 239). It is beautifully coloured. The eyes are blue in the male and greenish in the female; they meet for some distance in the middle line, and just in front of them are three simple eyes or ocelli in a nearly straight line. The compound

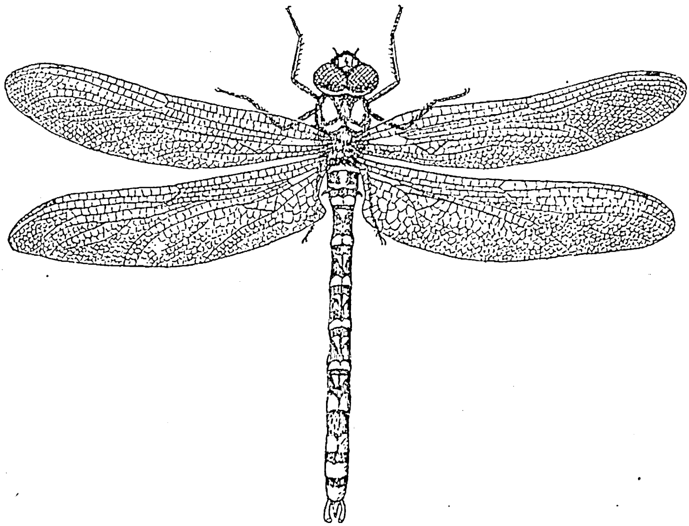

FIG. 239.—The Dragon-fly (*Aeschna cyanea*, male).

eyes are exceptionally large and prominent, containing more than 20,000 visual elements (see pp. 231-3). *Aeschna* is said to have better sight than any other insect—probably vision is not clear of an object more than six feet away, but the insect is certainly cognisant of a moving object at a much greater distance.[1] The antennae are minute bristles projecting forwards.

On the thorax are dorsal green spots and lateral yellow bands. Blue spots also run in pairs down the dark-coloured abdomen of the male, and yellowish-green spots similarly mark the female, the two spots on each of the last two

[1] See *Biology of Dragon-flies*, by R. J. Tillyard, 1917.

segments becoming confluent. On the front margin of each wing is an oblong dark mark or "stigma." The hind wings are slightly larger than the fore wings, and are broad at the base with a sharp, incurved angle in the male, but a rounded margin in the female. The thorax is necessarily large and thick to contain the powerful muscles which move the wings. At the end of the ten-jointed abdomen in both sexes is a small pair of processes known as the *claspers* or anal appendages, by means of which the male grasps the female; the male has also a median projection.

Food and Capture of Prey. The legs of the adult are thin and weak, being used for clinging to objects but not for walking; apparently they are also used in catching food. The Dragon-fly is a voracious eater of other insects, catching them as they fly. When it is flying, the legs are all turned forward under the mouth. Each leg is fringed with stiff hairs, and it is possible that they form a kind of net, in which the insects are caught before being conveyed to the mouth and masticated by the powerful mandibles. There is, however, some doubt on this point,[1] and more observations are desirable both on it and on the custom attributed to individual dragon-flies of frequenting special hunting-grounds.

R. J. Tillyard states that some of the *Aeschnidae* do valuable work in keeping down the number of gnats and mosquitoes, and one large dragon-fly has been known to eat forty house-flies within two hours.[2]

The mandibles, though strong, cannot inflict any noteworthy wound on the human hand; neither does the Dragon-fly sting, though the old mistaken idea that the pointed tip of the abdomen contained a sting has gained for the creature the undeserved names of the "Horse-stinger" and the "Devil's Darning Needle"!

Reproduction. The Eggs. At the mating time the male clasps the neck of the female with his anal appendage and flies with her "tandem-wise" (cp. Fig. 250). Previously he has transferred his sperm from the organ of secretion in the

[1] See *Natural History of some Common Animals*, by O. H. Latter, p. 101.

[2] "Some Dragon-flies and their Prey," by H. Campion, in *Annals of Nat. Hist.*, 1914.

9th segment to a special receptacle situated in the 2nd segment of his abdomen, and when flying united, "per collum," the female bends round her abdomen and applies it to the 2nd segment of the male, receiving the sperm cells into a special pouch, whence they issue to fertilise the eggs as they pass down the oviduct.[1]

After this has occurred, the eggs are deposited by the female upon water-plants, the stem or leaf of a plant just below the surface of the water being pierced by the sharply pointed ovipositor, which is projected from the end of her body. In each puncture is deposited one pale yellow egg, which is about $\frac{1}{16}$ inch in length.

The Larva. In three or four weeks, there emerges from the egg a larva which, though able for a time to swim freely by moving its legs, soon makes its way to the pond bottom and there walks about, though it still occasionally takes to swimming with a curious, jerky motion due to the sudden expulsion of a jet of water from the end of the tail.

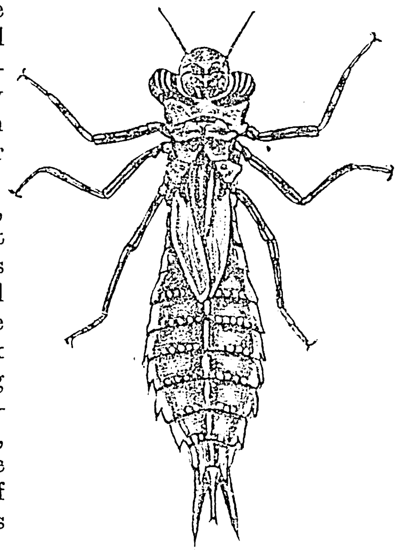

FIG. 240.—Full-grown Larva or Nymph of *Aeschna* (nat. size). (Seen from above.)

The larva is a dingy, ugly creature, with at first no trace of wings. It has a broad head with small antennae and very large compound eyes, a thorax of three segments bearing three pairs of well-developed jointed legs, and, in older larvae, the rudiments of two pairs of wings. The abdomen is broad and yet fairly long, ending in five pointed processes of which two are very small and form a lateral pair. These processes form a valve which can either close over the end of the alimentary canal, or can be widely

[1] *The Biology of Dragon-flies*, by R. J. Tillyard.

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opened at will, and so are of use in the anal respiration which is peculiar to Dragon-fly larvae.

Respiration. A pair of large spiracles is present in the larva behind the head, between the first and second segments of the thorax, and another pair is said to exist behind these, which, however, cannot be seen without dissection. In spite of these spiracles, the larva does not normally—at any rate when young—come to the surface of the water to breathe, as it would do if the spiracles were functional, but remains permanently below the water if this is fairly fresh, and it is evident, therefore, that it must depend on some other mode of respiration; this seems to be supplied by the modified "rectum," or last part of the alimentary canal which forms the structure known as the "branchial basket." The wall of this is ridged and folded, so that it is capable of being greatly distended, also it is supplied with six series of inwardly projecting gills, each penetrated by an enormous number of minute tracheal branches which are in connection with the main tracheae of the body. By the muscular expansion and contraction of the rectum, water is sucked in or expelled, at will, and thus the necessary supply of oxygen, dissolved in the water, is brought into contact with the tracheae and diffuses into them. If the water is foul, or if the air in it has been driven out by boiling, the larva comes to the surface and projects its tail into the air, which it takes direct into the rectum. A full-grown larva, instead of drawing in air through its tail, may make use of its thoracic spiracles, for these are open at this stage, though closed in the young larva.

Movement. The sudden ejection of water from the large anal chamber will often cause the larva to dart quickly forward through the water. When a captured larva is first set free from the hand into a bowl of water, it will often suddenly eject this anal jet, which may spurt up into the air for several inches.

Food and its Capture. The Dragon-fly larva is a very active hunter, stalking its prey unperceived owing to its dull coloration and its stealthy movements. Any soft-bodied aquatic creatures are attacked by it, even fish larger than itself. It has a most efficient weapon for seizing its prey in the so-called "mask" or modified lower lip.

The labium has developed into a single, jointed, arm-like structure with three distinct parts: there is a long segment, attached beneath the mouth, which when at rest extends backwards below the head and throat; connected with this by a kind of elbow-joint is another long segment which lies, when at rest, below the first, but which projects forwards; finally, at its free end are two sharply curved teeth known as the "forceps." The broad end of the second segment

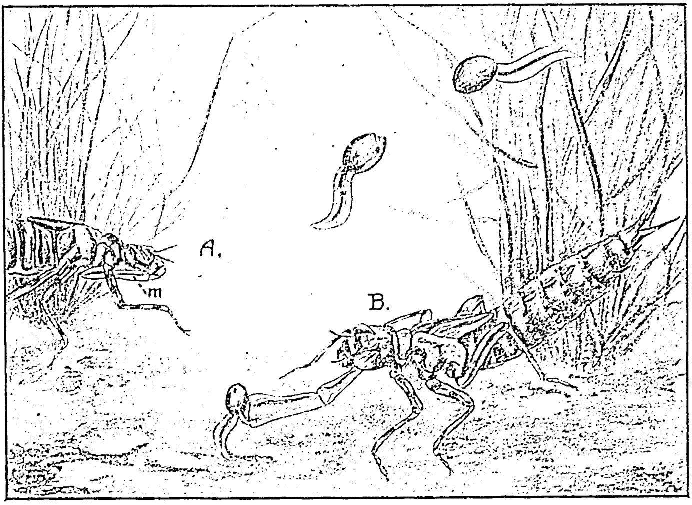


FIG. 241.—Two *Aeschna* Larvae hunting Tadpoles in a pond.

A, With mask, *m*, bent back under the head; *B*, with mask extended and holding a tadpole in its "forceps."

of this labium, with its "forceps," lies, when not in use, over the mouth, hiding the real jaws, and therefore the structure is termed the "mask" (Fig. 241, *m*).

When the larva has approached stealthily within reach of its prey, it suddenly shoots forward the whole "lip arm," at the same time opening wide the forceps and seizing the animal with them. The "arm" or "mask" is then pulled back with equal rapidity, so that the prey is held by the forceps against the mouth, where it is quickly eaten by means of the toothed mandibles and maxillae.

Metamorphosis.

Although at first the newly hatched larva has no trace of wings, after four or five moults rudiments of them appear as two small, backwardly extending lobes; these are attached at their bases to two horny plates which have previously grown up from the sides of the body, and which nearly meet in the middle line over the back. A larva with wing rudiments is often called a *nymph* (Fig. 240). Many moults occur before this nymph is full grown. In fact, the larval stage usually continues for from ten to fourteen months. By this time (*i.e.* probably in early July) the wings are about $\frac{3}{8}$ of an inch long, and the thoracic spiracles have become functional, otherwise the larva has changed but little, except in size. Now, however, the nymph ceases to feed, and climbs up some weed or projecting stump right out of the water, perhaps to a height of several feet above the surface. When it has found a suitable spot, the nymph clings firmly, in an upright position, to the support, and prepares for its last moult, when the remarkable change from the dingy, slow-moving larva to the brilliant, swiftly flying imago will take place. It may remain thus, motionless, for some hours, or even a whole day, before any further change occurs; but if the transformation is taking place rather late in the year (*e.g.* mid-July), or if the nymph has hesitated for several days before leaving the water, it may take place quite rapidly. It will suddenly be noticed that the skin over the eyes, which previously was dull and opaque, has become bright and transparent, owing to the brilliancy of the eyes lying underneath. Next the skin splits down the mid-line of the thorax, and the body within swells up, causing the split to extend

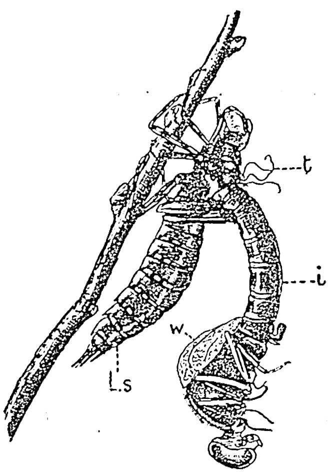


FIG. 242.—Early stage in the last moult of the Nymph of *Aeschna*.

i, Body of imago partly free from the old larval or nymph skin, *l.s.*; *w*, crumpled-up wings of imago; *t*, tracheal threads of nymph withdrawn from body of imago.

forwards right across the eyes. In this way the head and thorax, with the still minute wings, are freed, and next the legs are drawn out of the old skin, the thorax and head being strongly arched outwards to accomplish this, and, at the same time, to cast off the four chief tracheae, which are shed with the external skin. The tracheae remain behind, as two white threads attached on each side of the thorax of the larval skin

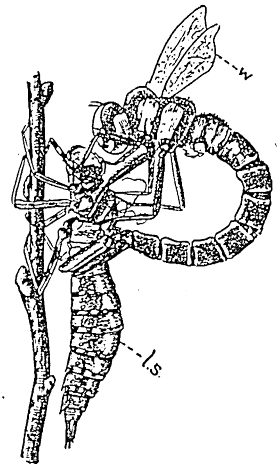


FIG. 243.—Stage 2 in the last moult of the Nymph of *Aeschna*, when the tip of the abdomen is being withdrawn from the old skin.
w, Wings of imago not yet expanded; *l.s.*, larval skin.

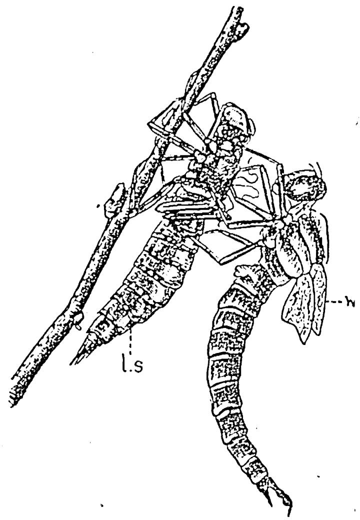


FIG. 244.—Stage 3 in the last moult of the Nymph of *Aeschna*.
Abdomen just freed from larval skin. Wings expanding and abdomen shrinking in width.

(Fig. 242, *t*). After this, the insect throws its head and thorax right back until they almost touch the abdomen (Fig. 242), and in this curious position—supported only by the tip of the abdomen, which remains inside the old skin—it rests sometimes as long as half an hour, waiting doubtless for its newly exposed legs and claws to harden, and for its body to gain strength for the sudden jerk forwards, with which finally the body is brought back into a more normal position, the claws grasping firmly the sides of the discarded skin (Fig. 243). Then it proceeds to withdraw the end of its abdomen, pulling it carefully out of the original split in

the thoracic wall, and having, therefore, to arch its whole body strongly to free it (Fig. 243), though as soon as it is free it is extended, and curves up away from the old larval skin (Fig. 244). The imago now usually abandons this, climbing up a few inches above it (Fig. 245).

There is, however, considerable further development to take place before the mature adult form is attained. The wings are still small and rudimentary, the vivid adult colouring has not yet appeared, and the abdomen has yet to shrink in width and increase in length.

The wings are at first soft, moist, and crumpled-looking (Fig. 244), but now they begin to expand very quickly, still held vertically side by side, but kept carefully apart from each other, the abdomen being curved away from them, so that they have all the room possible for their free expansion. At this stage the two layers of which they are formed seem to be slightly separated, and, if damaged, green blood flows freely from them; in fact it is the pumping of this blood into the hollow bag of the wing that causes its rapid expansion and gives it its characteristic greenish colour.[1] During the expansion of the wing, chitin is developed along the course of the veins forming the necessary supportive framework; ultimately the two surfaces of the wing fuse together except where traversed by a vein or nervure. In half an hour or less, the wings are fully expanded (Fig. 245), but still some hours of rest are needed before they are sufficiently firm and dry for flight. During this time the abdomen reaches its full length, but gets thinner, letting fall gradually, drop by

FIG. 245.—Last stage in the metamorphosis of *Aeschna*, the wings of the imago almost fully expanded.

[1] *The Biology of Dragon-flies*, by R. J. Tillyard, 1917.

drop, the liquid which distended it; slowly also the characteristic colouring of the Dragon-fly appears. Finally, perhaps three hours after the imago began to withdraw itself from the larval skin, the wings are for the first time spread out at right angles to the body, and, after moving them once or twice, the Dragon-fly sails off into the air and begins its active predatory life, which lasts until the cold of winter renders further existence impossible to it.

Tennyson must have seen this metamorphosis when he wrote:[1]—

> "To-day I saw the dragon-fly
> Come from the wells where he did lie.
>
> "An inner impulse rent the veil
> Of his old husk: from head to tail
> Came out clear plates of sapphire mail.
>
> "He dried his wings: like gauze they grew;
> Thro' crofts and pastures wet with dew
> A living flash of light he flew."

Other British Dragon-flies.

Very nearly 2000 species of Dragon-flies have been described, and there are many more as yet unnamed, but of all these only about 46 are British.

The four families most common in Britain are those the typical genera of which are, respectively, *Libellula*, *Aeschna*, *Agrion*, and *Calopteryx*. Of these, the two former belong to the sub-order **Anisoptera**, both being large forms with the hind wings broad at the base and spread horizontally or depressed when at rest; both also have larvae with broad abdomen and anal respiration; the two latter belong to the **Zygoptera**, in which both pairs of wings are alike and narrow at the base, and are usually held folded back vertically when at rest; the body has a very slender abdomen, and the larva also has a small, slender body, with three flap-like processes at the end of it which are tracheal gills.

Sub-Order: Anisoptera.

Family 1: Libellulidae

The imago of a Libellulid has a broad and thick, though

[1] *The Two Voices.*

tapering, abdomen except in the genus *Sympetrum.* The compressed eyes meet on the top of the head, and there are three ocelli arranged in a triangle. The wings are extended when at rest. The larva has a thick, short body with slender, weak, but rather long legs. The eyes are farther apart and the head squarer than in *Aeschna.*

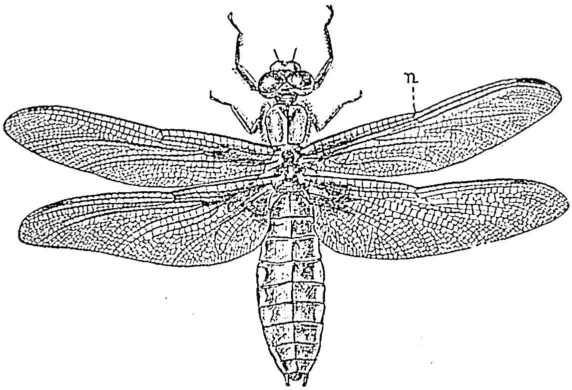


FIG. 246.—*Libellula depressa* (nat. size).
n, Node of the wing.

The larvae of these Dragon-flies are usually to be found in very dirty stagnant water, and are at first rather like little spiders, but with only six legs, with which they swim through the water.

The female Libellulid has no ovipositor, and the eggs are just dropped into the water of the pond.

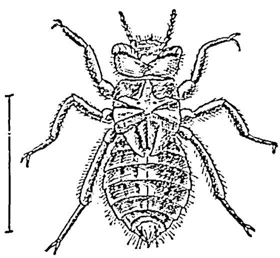


FIG. 247.—Nymph of *Libellula.*
The line to the left shows the actual length.

Genus 1. **Libellula.**—A broad-bodied form, with a dark triangular stain at the base of the hind wings; the abdomen is not spotted dorsally, and it is thicker in the middle, so that its sides are not parallel.

In *L. depressa* (Fig. 246) the abdomen is blue in the male and brownish yellow in the female. This

Dragon-fly has the habit of resting on a special twig and returning to it again and again if disturbed. It has a powerful flight, and has been seen sometimes wandering for long distances, even out to sea, in company with many others of its kind.

In *L. quadrimaculata*, a very common species, there is a dark spot at the node of each wing as well as at its apex. Both sexes are brown, with lateral yellow spots on the abdomen and a yellowish-brown band along the front margin of each wing. This species also has a migratory instinct; flocks of many thousands have occasionally been seen off our East Coast.

Genus 2. **Sympetrum.** — Smaller forms than *Libellula*, with a narrow abdomen, and wings without the dark triangular stain at the base, though a slight yellowish stain may be present. The body of the male, except in the black species, *S. scoticum*, is marked with brilliant red pigment, absent in the females, which are usually brown. The length of the body is from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches, whilst that of *Libellula* is from $1\frac{1}{2}$ to 2 inches. *S. striolatum* is one of the commonest British Dragon-flies.

Genus 3. **Orthetrum.**—Wings clear and unstained; the abdomen may be narrower than in *Libellula* or as broad. The abdomen in the male is blue, in the female brown. Found in the South of England, but not very common.

Family 2: Aeschnidae

The Dragon-flies of the family *Aeschnidae* are large forms in which, as in the *Libellulidae*, the eyes usually meet on the head for some distance; but the three ocelli are nearly in a straight line on the front of the head, and the abdomen is very long and narrow. The larva also is larger, with a relatively longer abdomen and stronger legs, than a *Libellula* larva.

Genus 1. **Aeschna.**—The base of the inner margin of the hind wing on the male is characterised by having a sharp, incurved point. The male is dark brown, much spotted with blue in the rare, northern, *A. coerulea*, or brown with blue and yellow markings in the common *A. cyanea*, or almost entirely brown in *A. grandis*. This last species is the one that so commonly visits

gardens even near towns, flying high over the trees. The length of the body is $2\frac{1}{2}$ to 3 inches. The details of the form of the anal appendages in the male are specific characteristics that can be used in identification.[1]

Genus 2. **Anax.**—Large, beautifully bright forms, the body of the males blue, and of the females green, with a long irregular black line down the back of the abdomen. Length 3 inches. *A. imperator* is not uncommon in the south.

Genus 3. **Cordulegaster.**—The name is derived from the Greek *cordule*, a club, the genus being so called from the shape of the abdomen, which in the male is thin in the centre and thicker at both ends. The body is greenish-black, with transverse yellow markings. Length 3 inches or more. The larva of this form is found in running streams; it is peculiar amongst British dragon-fly larvae in having diverging wing-sheaths.

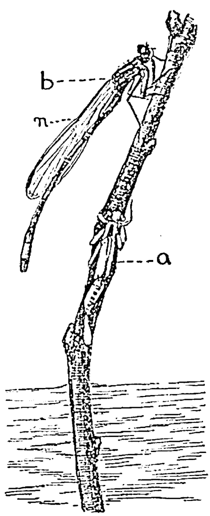


FIG. 248.
One of Agrionidae.

a, Empty nymph skin; *b*, imago which has emerged from *a*; *n*, node of wing.

Sub-order: Zygoptera.

Family 1: AGRIONIDAE.

The members of this family are relatively small forms, and the eyes are wide apart and large. The abdomen is slender and usually brightly coloured; the wings very narrow, transparent, and uncoloured, except for the small dark patch or stigma present on the front of each wing in both sexes. There are only two small cross veins in the space between the node of the wing and its base. The larva is a slender brown or greenish-coloured little creature, with three delicate, leaf-like plates at the end of the body; these are tracheal gills, though other means of respiration, probably rectal, must exist, since these appendages are sometimes bitten off by enemies, and yet the larva continues to live; it must therefore breathe by other means until the lamellae are

[1] See Tillyard, *op. cit.* pp. 340 and 32-37.

renewed at the next moult. These small dragon-flies, when adult, may often be seen mating close above the surface of the water; the male holds the female with his claspers just behind her head; she then bends her abdomen right round under his body and applies it to his second abdominal segment whence she receives the sperms; she then curves her body down into the water and deposits the fertilised egg (see Fig. 249); they then fly off together in the "tandem" position, shewn in Fig. 250, and repeat the process elsewhere.

Genus 1. **Agrion.** — Abdomen blue marked with black or a blackish bronze. Length of body about $1\frac{1}{4}$ inches. The larvae are brown or grey-green. The larval tracheal lamellae are either constricted at one point or are what is known as "nodate," the "node" being merely the point where the basal, toothed edge of the lamella gives place to a smooth edge. *A. puella* is a very common species; the male has a brilliant blue body.

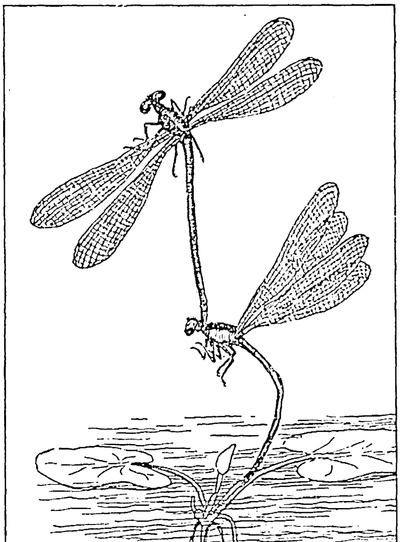


FIG. 249.—Dragon-fly (*Pyrrhosoma*) ovipositing.

Genus 2. **Pyrrhosoma.**— Abdomen crimson with some bronze colouring, male more crimson than female. Tracheal gills neither constricted nor clearly nodate. Length $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. *P. nymphula*, and the slightly smaller *P. tenellum*, are both common.

Genus 3. **Enallagma.** — The imago of this very common form differs only in slight details from *Agrion*, but its larva is of a bright-green colour.

Genus 4. **Lestes.**—Abdomen of male green and blue, of female

green and brown. The members of this genus rest with their wings half-spread ; they are not very common. Their larvae have simple, elongated tracheal gills.

FIG. 250.—*Lestes Sponsa*, male and female flying "tandem."

Family 2: CALOPTERYGIDAE

The beautiful little Dragon-flies of the family *Calopterygidae* have narrow bodies of a brilliant metallic blue or green, according to whether they are male or female. Their wings are broad at their free ends but narrow at the base ; they have no stigma in the male, and in the female a white one only, a point which, together with the coloration of the wings, aids in distinguishing this genus from the genus *Agrion*. The eyes are far apart, as in the *Agrionidae*. Because of their beauty and elegance they are often called "Demoiselles." They fly with rather a weak, fluttering motion, usually several together, remaining long near the same spot. The larvae have tracheal gills of the same type as those in *Agrionidae*, but the two lateral gills are triangular in section, only the central, smaller one being flat (lamellar) as in

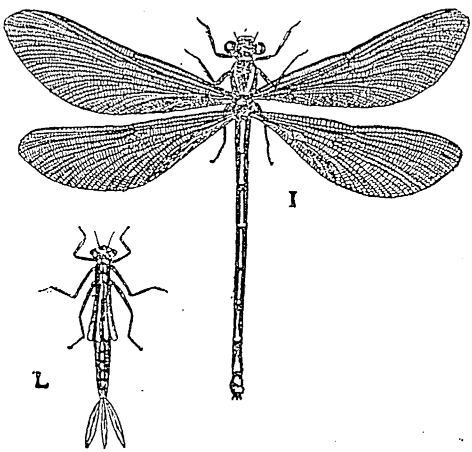


FIG. 251.—*Calopteryx virgo* (nat. size).

I, Imago ; *L*, full-grown larva or nymph.

Agrionidae. The lamellae are marked with dark transverse bands; they are nearly equal in size in *C. virgo*, whilst in *C. splendens* the central one is considerably shorter than the others.

Single genus. **Calopteryx** (Gk. *kalos*, beautiful; *pteron*, a wing).—There are only two species of this genus, *C. virgo*, in which the wings are coloured almost entirely blue in the male, whilst in the female they are yellowish brown; and *C. splendens*, in which the wings of the male have a large blue patch on them and the body is blue, whilst the wings of the female are greyish and her body is green.

Practical Notes on Dragon-flies

1. So far as possible the whole life-history of an *Aeschna* and an *Agrion* should be followed. In any case, full-grown nymphs should be obtained in the summer, and their wonderful metamorphosis into winged insects watched throughout, drawings being made, or photographs taken, at noted intervals.

When the nymphs are brought home from the pond, they should be carried loosely packed in damp water-weeds in a tin, and must be transferred to a tank where there is plenty of vegetation, and, if they are nearly full grown, where some of the plants rise well above the surface of the water; indeed it is often advisable to put in several thick, rough sticks weighted at the lower end and projecting two feet above the water, so that plenty of easy means of exit are provided for the nymphs. If this is neglected, or inadequate exits are provided, the Dragon-fly when it emerges may wet its wings and be seriously injured.

If the nymphs in the tanks are not full grown, they will need regular feeding, and unfortunately it only seems possible to keep them healthy by giving them living food. Tadpoles, freshwater shrimps, and insect larvae form their natural diet, but they may sometimes be induced to feed on blow-fly larvae ("gentles") and pupae.[1] When about to undergo their transformation the nymphs will be seen to cling on to the sticks just at the surface of the water, with their head and shoulders out of the water. A careful watch should then be kept, and when once they have climbed right up the stick they should not be left until the whole marvellous transformation has been seen; it may take two or three hours to complete the process.

[1] They will sometimes eat raw meat, but I have not been able to rear them successfully on this diet only.

2. Study carefully the appearance and habits of any dragon-flies you see, identifying the species by reference to *British Dragon-flies*, by W. J. Lucas, in which coloured plates and descriptions of all chief genera and species are given. *The Biology of Dragon-flies*, by R. J. Tillyard, should be consulted for more detailed study.

3. To rear Dragon-flies from the egg is a somewhat difficult task. The female insect should be caught just as she is ovipositing; then, holding her gently by her front wings, her abdomen should be dipped just below the surface of the water in a small tube in which a little mud and other debris has been sunk. She will then very probably continue to lay her eggs, and these, if kept in flat shallow dishes with plenty of vegetable matter and mud in them, will hatch in from five days to three weeks according to the species.

The young larvae may be reared in small dishes in which there is plenty of duckweed and a supply of minute animal organisms, mainly Protozoa, for food; later they may be fed on water-fleas and small gnat larvae.

CHAPTER XXII

INSECTA (*continued*)

Order: EPHEMEROPTERA[1] (THE MAY-FLIES)

THE May-flies, like the Dragon-flies, have aquatic larvae, and there is a gradual metamorphosis, the wings growing rapidly at the last moult. The second pair of wings is always much smaller than the first pair. The head bears short antennae, and three ocelli, as well as a pair of large, sometimes subdivided, compound eyes. The mouth-parts are very degenerate, for the imago does not feed during its short life. The eyes of the nymphs of *Ephemeroptera* are compound.

Type: **The Common May-fly** (*Ephemera vulgata*)

The history of these insects is one that holds the imagination. For two or three years, the dingy little brown larvae may live partially buried in the mud or decaying vegetation at the bottom of pond or river, swimming actively, if disturbed, by whisking their tails, but taking refuge as soon as possible in the mud or amongst the vegetation, remaining very still with tail uplifted, as shown in Fig. 252. Then, one evening in summer, hundreds of them rise together to the surface, split their larval skins, and, in a few brief moments, up dart the winged flies, soon, however, to come to rest again in order to throw off still another skin, after which their development

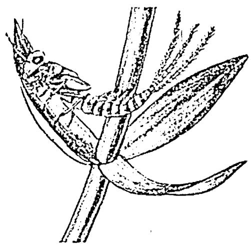


FIG. 252.—Larva of the Common May-fly, resting on a piece of Canadian Water-weed. ×2.

[1] Order *Neuroptera*, family *Ephemeridae* in *Camb. Nat. Hist.*

is complete, and the mature insects (known to anglers as "Grey Drakes") enter upon the last, short but merry, phase of their existence.

All through their previous life feeding has been their chief activity; now they feed no more—they have no mouth. For a brief half-hour, or at most during the few short hours of a summer night, the fragile little flies dance in swarms together up and down, sometimes high in the air, often so close to the water that the whisks at the end of their tails sweep the surface. Now they are about to fulfil the function which distinguishes this phase of their life—now they mate, and each female drops on the surface of the water a batch of small, disc-shaped eggs, which slowly sink, scattering as they do so. Their destiny is now fulfilled, and gradually the myriad flies that filled the air sink and die.

For several nights in succession such hosts of May-flies will rise from the same piece of water, and the same phenomenon can be witnessed; then all is still, and the future of the race is hidden in the life-germs within the eggs that lie deep in the water.[1]

The Larva. The larvae of most of the different genera of May-fly live in running water, but *Ephemera vulgata* is very common in ponds and ditches, as well as in slow-running streams. As soon as the larva escapes from the egg, it burrows in the mud at the bottom of the water, thus gaining protection from its enemies. It has at first no trace of wings, but merely a little, segmented, rather worm-like body, with, however, a pair of long antennae and six legs. Slowly, accompanied by many moults, the development proceeds, until a full-grown larva or nymph exhibits the form shown in Fig. 252. Attached to the thorax can be seen the rudiments of two pairs of wings, and projecting freely from the abdomen on each side is a series of narrow, plate-like gills, fringed with respiratory hairs.[2] The tracheae send closed branches into these gills, for they are typical "tracheal gills"; by waving them about in the water, diffusion of fresh air into the tracheae is facilitated.

At the end of the tail are three longer processes which are additional respiratory organs of a peculiar and unusual kind,

[1] See *Study of Animal Life*, by J. A. Thomson (1917), pp. 112, 113.

[2] The form and position of the gills vary in different genera.

for they contain prolongations of blood-vessels, in place of tracheae, the blood being directly purified by the air in the surrounding water instead of being entirely dependent on the air brought in by the tracheae. Perhaps this special adaptation is necessitated because of the scarcity of air in the mud in which the larva lives.

The burrow made in the mud is U-shaped, for the larva burrows down head foremost, and then works gradually round and up again. A current of water is made to flow constantly through it by the motion of the tracheal gills. The larva feeds to some extent on organic matter present in the mud which it swallows, and also on small creatures; sometimes, however, its prey is almost as big as itself, for the mouth and jaws are quite well developed at this stage, though in the adult so atrophied as to be practically absent.

Change of Habitat.

When ready to leave the water, the nymph swims to the surface, and with remarkable rapidity the skin is split and the winged form rises into the air; there is no long, gradual extrication of limbs and body nor slow growth of wings, as seen in the Dragon-fly, and yet the process must be much the same, though condensed into so short a time that it is almost impossible to follow it.

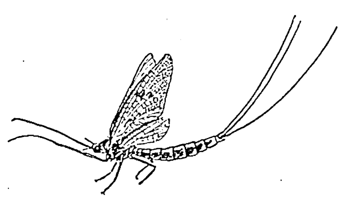


FIG. 253.—Adult May-fly (*Ephemera*). (Natural size.)

Imago.

The process is also peculiar in that, after the first flight into the air, the insect again comes to rest, and throws off very rapidly a second skin, changing its shape and colour slightly as it does so, becoming grey instead of green, and exposing wings of a rather more delicate texture, shorter antennae, and longer tail filaments. May-flies are the only insects which moult after they have attained the power of flight.

The tail whisks are very characteristic. There are always three in *Ephemera vulgata*, but two only in some other species.

The minute antennae are very inconspicuous; the front pair of limbs is turned forwards, and may be mistaken for antennae until carefully examined.

In most May-flies, two pairs of wings are present, and their

venation recalls that of the Dragon-fly; the hinder wings, however, are relatively small, a characteristic which serves to distinguish them from the *Plecoptera* (or Stone-flies), which are next to be considered.

Order: PLECOPTERA [1] (THE STONE-FLIES)

In the Stone-flies, the wings consist of a transparent membrane with a network of nervures as in Dragon-flies and May-flies, but the "nervures" are much stronger and more conspicuous; also the hind wings are much larger, though not longer, than the fore wings, and are broad at the base, all the marginal part having a more complex venation than the rest of the wing. The antennae in this family are long and flexible. As in the two previous families, the larva is aquatic, and the metamorphosis is gradual: but the difference between adult and larva is slight, except for the possession of wings by the former.

The Common Stone-fly (*Perla bicaudata*)

Perla bicaudata frequents river banks in June, seeming

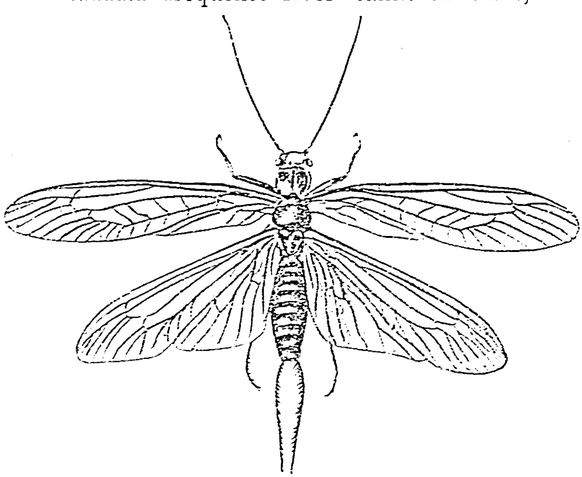


FIG. 254.—The Common Stone-fly (*Perla bicaudata*). (Natural size.)

specially to favour rapidly flowing streams with stony beds.

[1] Order *Neuroptera*, family *Perlidae*, in *Camb. Nat. Hist.*

This yellowish-brown fly is rather sluggish in its habits, sitting for long together on a stone by the water, with its long wings folded flat over its body so that only one pair can be seen. It flies slowly and heavily, and can easily be caught in the hand. It has a pair of long antennae projecting in front, and also a pair of delicate, jointed appendages, "cerci," at the end of its tail.

The thorax is peculiar, for the three segments which form it are unusually large and clearly marked, forming with the head about half the length of the body; in consequence the bases of the two pair of wings are rather widely separated.

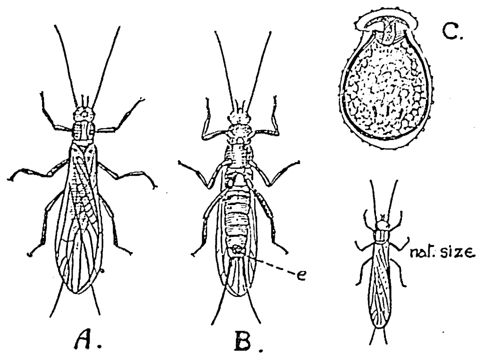


FIG. 255.—*Chloroperla virescens.*

A, Dorsal view; *B*, ventral view; *e*, egg mass being discharged; *C*, one egg enlarged.

The insects mate on the ground, and the small black eggs, held together by a delicate, membranous capsule, are carried for some time adhering to the abdomen of the female, and are then dropped in the water. Similar eggs are shown in Fig. 255, which represents the closely allied genus, *Chloroperla*, a yellow and much smaller fly, known as the "Yellow Sally."

The Larva. The Stone-fly larvae, sometimes known as "Creepers," which hatch from the eggs, can swim freely in the water by the movements of the body, but they usually hide under stones. This larva, like the imago, bears two long antennae on its head, and two antenna-like appendages at the end of its body. It breathes by means of small tufts of thread-like tracheal gills, of which there are two pairs on each

thoracic segment and one pair on the last segment of the tail. These "creepers" are carnivorous, feeding on smaller aquatic larvae, biting them with their strong mandibles. The larval stage endures for two or three years.

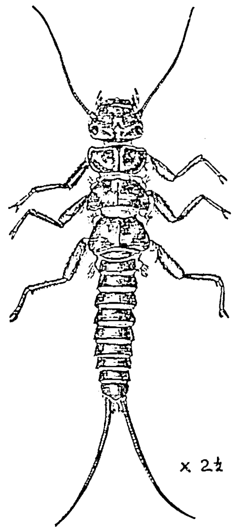


FIG. 256.—Larva of *Perla bicaudata.*

Change of Habitat. When the time has come, the nymph leaves the water, climbing on to some projecting rock or plant. The skin swells and splits over the thorax, and then the body is withdrawn from it. The wings expand, and after a few hours the tissues have become dry and firm, and the insect flies off, generally, however, remaining close to its former habitat. It does not feed, and only lives a few days.

The Willow-fly (Nemoura). The Willow-fly has a very similar life-history and structure, but the two long processes at the end of the body, though present in the larva, are lost at the last moult. The separation of the bases of the two pairs of wings is very marked in this genus.[1]

[1] For practical notes on *May-flies* and *Stone-flies* see p. 356.

CHAPTER XXIII

INSECTA (*continued*)

Order: Neuroptera

This order differs from the three just considered in having a "complete" metamorphosis, *i.e.* one with a quiescent pupal stage. There are four membranous wings, the difference in size of the two pairs being but slight. They are held over the back obliquely, meeting in a ridge over the middle line; the veining is fairly simple and conspicuous. The head bears long antennae. The long-legged larvae of the Alder-flies are aquatic, but there are other members of the same family—the Snake-flies—which have terrestrial larvae. In all cases the larvae have biting jaws.

Family: Sialidae (the Alder-flies or Humpbacks)

The Common Alder-fly (*Sialis lutaria*).

These flies can be readily recognised by their long black antennae and darkly-veined, dusky wings, the upper pair of which folds over the lower pair when at rest, the hinder part of each wing sloping away at a very marked angle from the

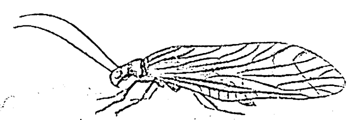


Fig. 257.—The Alder-fly (*Sialis lutaria*). (×2.)

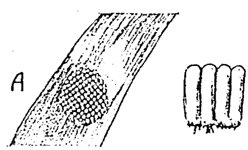


Fig. 258.—Eggs of Alder-fly. *A*, Natural size and position; *B*, a few enlarged and seen from the side.

mid-line where the two meet (Fig. 257). They fly heavily, and will often begin to run away before they take to flight. The body is thicker relatively to its length, and the antennae, though long, are shorter than in the Caddis-fly, for which it

is sometimes mistaken; also its wings are free from the small hairs which are characteristic of Caddises (see p. 357).

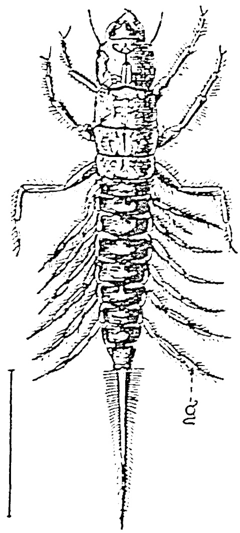


FIG. 259.—The Larva of the Alder-fly.
g, One tracheal gill.

The Eggs. The eggs are laid, not in the water, but on a plant, a stone, or a piece of wood, sometimes some yards away from the stream or river in which the larvae will live. The eggs are cylindrical, and are to be found in early May deposited in clusters of some hundreds together, neatly arranged in a patch with their outer, pointed ends free (Fig. 258).

The Larvae. When the larvae hatch, they have to wriggle their way down to the water, and many of them are said to lose their way and never reach their goal. The larval aquatic life is spent chiefly on the mud at the bottom of the water, and it lasts about a year. The head of the larva bears two short antennae and has well-developed mandibles, with which it attacks the other aquatic larvae on which it feeds. The thorax is large and very clearly divided into three segments, which bear three pairs of legs; the abdomen has the usual ten segments, and bears seven pairs of jointed, filamentous tracheal gills, which curve upwards in life and give the larva a characteristic appearance. The last abdominal segment is very peculiar, being long and narrow and very pointed, and containing two air-tubes, so that it acts as an extra tracheal gill.

Metamorphosis. When full grown, the larva is about one inch long. It then leaves the water and hides itself in the damp earth, sometimes several yards away. Having formed a little cell for itself, it casts its skin and exposes the quiescent pupa, with wing rudiments now apparent. The wings and legs of the pupa are not glued to the body, but enclosed in a special skin which is shed later. This stage lasts two or three weeks; then the fly emerges, creeps up some object near by to dry its wings, and soon takes to flight, never, however, going far from its native spot.

Family: CHRYSOPIDES (LACEWING-FLIES).

The *Chrysopides*, another family of the Neuroptera, resemble the Alder-flies in having a complete metamorphosis, with a quiescent pupal stage in which the wings become for the first time apparent, but differ from them in having much more delicate bodies and transparent, lightly veined wings; also they are entirely terrestrial, the larvae inhabiting land plants and feeding on green-fly. The mandibles and maxillae are modified into piercing and sucking organs.

The Gold-eyed Lace-fly
(*Chrysopa vulgaris*).

These flies have a rather thin, small body, with a relatively long abdomen. They are easily recognised by their long antennae, and their four similar and very delicate transparent wings, which when at rest roof over the body as in Fig. 260, *i*. Both body and wings are of a pale-green colour, and the eyes are brilliant and metallic-looking.

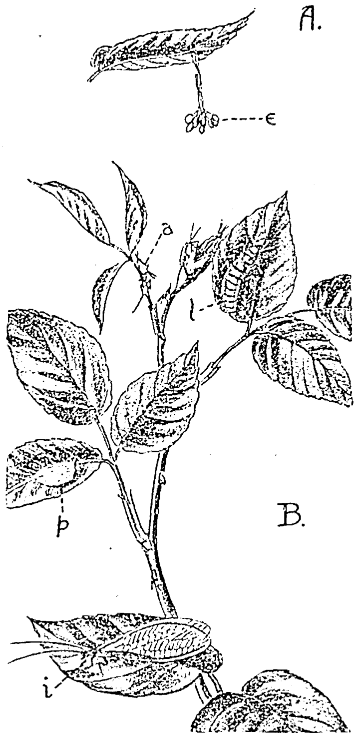


FIG. 260.—The Lacewing-fly (*Chrysopa vulgaris*).

A, Cluster of eggs, *e*; *B*, rose twig infested by *Aphides*, *a*, and harbouring the lacewing-fly in various stages; *l*, larva of lacewing-fly; *p*, pupa; *i*, imago. (Nat. size.)

The Eggs. The eggs are peculiar, for each is borne at the tip of a stalk several times the length of the egg itself; clusters of them are frequently to be found hanging from a leaf of lime or rose. Sometimes the egg-stalks

are intertwined, so that there is a little bunch of eggs (Fig. 260, *A*); sometimes each stands alone.

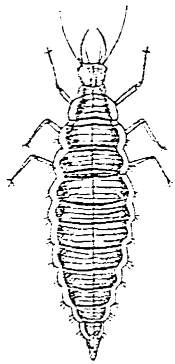


FIG. 261.
Larva of Lacewing-fly. (× 4.)

The Larva. The larva, when full-grown, is about half an inch long, and of a pale pinkish-yellow colour. It bears round its mouth specially modified, sickle-shaped jaws, with which it pierces the body of its prey and sucks up its juices. In this way it destroys large quantities of green-fly.

The Pupa. Finally, it spins round itself a little, almost globular cocoon of silk threads, which are given out from the last segment of the tail, and manipulated by the jaws into the required shape.

PRACTICAL NOTES ON CHAPTERS XXII. AND XXIII.

1. Those forms with aquatic larvae, such as *May-flies*, *Stone-flies*, and *Alder-flies*, may be found in many ponds and rivers, but they are not at all easy to keep alive in an aquarium. If the attempt is made, the tank should be filled with pond water, and at the bottom there should be a fairly thick bed of earth with plenty of vegetation; if possible, artificial aeration should be supplied.

May-fly larvae are plentiful in most ponds and rivers; Stone-fly larvae are to be looked for under the stones in clear streams in the early summer. Alder-fly eggs are very frequently to be found on the plants growing along the bank of a river, and a little net-dipping in the mud at the river bottom will probably produce some larvae. If full-grown larvae are kept in a tank, it is indispensable that facilities be given them to leave the water and burrow in soil for their pupation.

2. The *Lacewing-fly* of the garden is a far more satisfactory subject for study, for its whole history can be traced in its natural habitat, or, if more convenient, in a well-ventilated box in which shoots infested with *Aphides* should be placed, so as to yield a good supply of food.

CHAPTER XXIV

INSECTA (*continued*)

Order: TRICHOPTERA [1] (CADDIS-FLIES)

CADDIS-FLIES differ in several important respects from the Neuroptera. Specially to be noted in them are the hairs that more or less cover the wings, and make them somewhat opaque—the characteristic which has led to these forms being grouped in a special order, *Trichoptera.*[2] The nervature of the wings is peculiar in that there are very few transverse nervures. The broad hind wings are folded fanwise under the front wings when at rest, the latter being merely laid obliquely over the back and sides, as in the Alder-flies. There is a well-marked metamorphosis with a quiescent, aquatic pupal stage. The pupa, however, just before moulting the pupal skin, becomes active, and swims to the surface. The antennae of the imago are thread-like, and the mouth-parts are reduced, the mandibles being absent or very rudimentary, though present in the pupa (see p. 364).

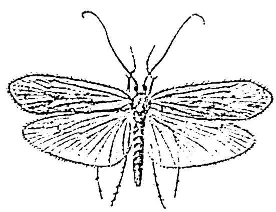


FIG. 262.—Caddis-fly.

Life-history of a Caddis-fly.

The rather moth-like, dull-coloured Caddis-flies are often to be seen on plants by the water side, or flying rather feebly close by (Plate III., *I*).

[1] Order *Neuroptera*, sub-order *Trichoptera*, in *Camb. Nat. Hist.*

[2] Greek *thrix*, *trichos*, hair; *pteron*, a wing.

Eggs. The eggs are laid in the summer, in a mass surrounded by jelly. They are either dropped by the female at the water surface, or in some cases she is said actually to enter the water and deposit the mucilaginous egg-mass on some water-plant stem, or other object (Plate III., *E*). The egg-mass is sometimes in the form of a jelly-like rope, which may be an inch or more long, or it may be a ring, or simply a flat disc of jelly. The eggs, which are often greenish in colour, are clearly to be seen inside.

The Larvae or Caddis-worms. The larvae hatch out after two or three weeks, and at once begin to make for themselves little protective cases out of any suitable material that may be at hand in the water. When the larva is full grown, its case has usually a characteristic appearance according to the species which has made it. One such case is shown in Fig. 264, *P*, with the caddis-worm projecting from one end. The larva under normal conditions never exposes more than its head and the first three segments of the body, all of which are protected by a brown, chitinous skin. The rest of it can only be seen when it has been induced to leave the case. This is easily accomplished by cutting the case carefully open, or by prodding it from behind very gently with the head of a pin or some other blunt object; the caddis-worm will then, though apparently with great reluctance, leave its case, and expose the soft, defenceless hind end of its body. Its structure is shown in Fig. 263.

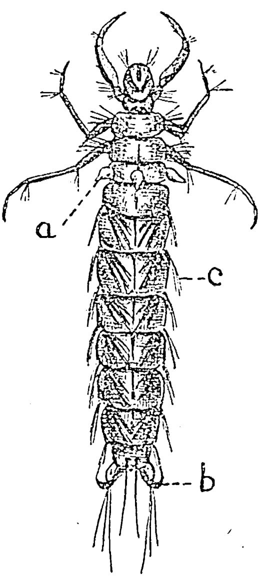


FIG. 263.—Larva of the Caddis-fly, the "Caddis-worm." ($\times 2\frac{1}{2}$.)

a, Fleshy protuberances; *b*, abdominal hooks; *c*, tracheal gills.

There are three distinct thoracic segments behind the head with its two simple eyes, and each of these bears a pair of relatively long, jointed legs on which the larva crawls actively about. Behind this region are nine abdominal segments, all of which, except the first and the

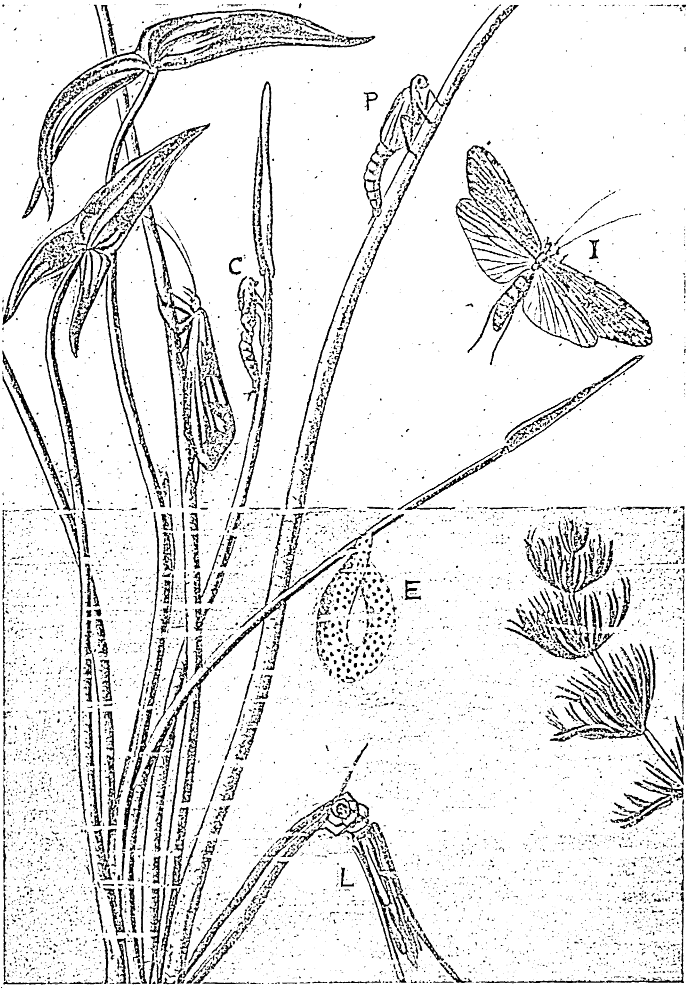


Plate III.—To illustrate the Life-history of a Caddis.

E, Eggs immersed in a jelly-like mass ; *L*, larva ; *P*, pupa ; *C*, cast pupal skin ; *I*, imago.

last, bear on each side a bunch of soft, white filaments, some of which often float out at the side, whilst some are laid across the back, crossing those from the other side (see Fig. 263). These are the breathing organs, or *tracheal gills*, which contain extensions of the tracheae, so that the air in them is only separated from the water by a very delicate membrane, and can be readily oxygenated from the oxygen dissolved in the water; for this process, however, it is necessary that there should be a constant stream of water through the case and over the gills. This is caused by the movements of the abdomen, and is facilitated by the structure of its first and last segments. The last bears a pair of strong hooks, which hold the caddis firmly to the end of its case (Fig. 263, *b*); the first has on it three white, fleshy processes or tubercles (Fig. 263, *a*), which can be retracted or extended, and which apparently serve to keep the body fixed at this point by the pressure of the tubercles against the inside of the case. The second and third abdominal segments lie close under the top of the case, the dorsal, median tubercle being much shorter than the other two; at this point muscular contractions occur at intervals, which cause an undulatory movement to pass down the body, driving the water out of the open hind end of the case, and thus causing more to enter in front. These movements can be made apparent by repeating the experiment devised by Professor Miall, in which a caddis-worm was induced to make a transparent case of small, regularly cut pieces of mica, an experiment quite easy to carry out if the right kind of caddis-worm is selected, namely, such a one as *Phryganea grandis* (Fig. 264, *P*), which constructs a regular and smooth case.

Respiration of Larva.

Caddis-worm Cases.

Caddis-worm cases vary greatly according to the species which makes them (see Fig. 264), but all are alike in being open at both ends, though the opening at the back is often very small, and all are made of material picked up by the larva and gradually built into a case. The larvae live usually in the shallow, clear water round the margin of a pond or stream, and by visiting different pieces of water in which the nature of the pond-floor varies greatly, a large variety of cases may be quickly obtained. The case often so closely resembles the ground

it lies on, that it may be some time before the eye detects it, for even when moving it often appears at first merely as if a little piece of the debris at the bottom were shifting. It is very interesting to watch the manufacture of a case, or the adding of a new length to it when it has become too small for its growing inhabitant. If it is a new case that is to be made, two pieces of the material chosen are seized by the

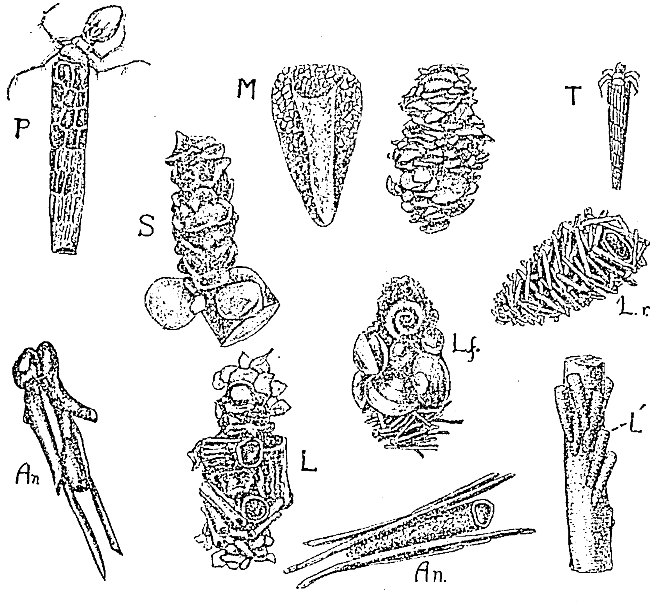


FIG. 264.—The Cases of different genera of Caddis-worms. (Nat. size.)

P, *Phryganea*; *An*, *Anabolia*; *S*, *Stenophylax*; *M*, *Molanna*; *L* and *L′*, *Limnophilus*; *L.f*, *Limnophilus flavicornis*; *L.r*, *Limnophilus rhombicus*; *T*, *Triaenodes*.

front legs, which are turned forward on either side of the head; the pieces are bound together by silk threads given out from the salivary glands below the mouth, and a third is bound to them in the same way. The process is repeated until a complete ring is formed, which is then pushed over the larva's head, and a fresh row of fragments added in front, until the case is of sufficient length. Many of the cases are very rough and irregular on the outside, but all are lined with a smooth silken layer within.

The cases of the genus *Phryganea* are perhaps the most beautiful, for they are made of small, more or less rectangular pieces of green leaf, which have been cut by the larva, and so arranged that they form a spiral band round the case (Fig. 264, *P*).

The little *Triaenodes* makes a similar case, but much smaller and more tapering (Fig. 264, *T*). It is a form which can swim freely in the water, for it is small and light, and its legs are unusually long, the hind legs being fringed with hairs.

The genus *Limnophilus* varies very much in its case-making taste. The species *L. rhombicus* constructs the very common spiky case made of tiny sticks or green stems placed transversely (Fig. 264 *L.r*). *L. flavicornis* specially favours the shells of small bivalves and snails, and is even regardless of whether or no the shells are still inhabited by their rightful owners, who may be carried off and remain for the rest of their lives fixed to the case of the caddis. Other species of *Limnophilus* make curved tubes of fine sand, or straight sandy tubes which are often found, many together, fixed to a piece of stick (Fig. 264, *L'*).

Anabolia cases can usually be recognised by the long pieces of stick that are fastened along the sides of the compact, central case of tiny stones, or sand, or vegetable matter. These long additional sticks are supposed to give the case greater buoyancy in the water, so that it can be more easily carried along by the caddis-worm (Fig. 264, *An*).

Stenophylax forms a case of small stones, and attaches it to a big stone; this is advantageous since it lives in running streams, and so has to guard against the danger of being swept away by the current (Fig. 264, *S*).

Molanna forms a pretty case of sand, the top being curved, and prolonged into a shield-like projection over the head and on either side of the body (Fig. 264, *M*).

Some caddises of the genus *Hydropsyche* make fixed cases of stones, which are inhabited jointly by several larvae, who go out to seek their prey and then return to their retreat.

Another very interesting form, *Plectrocnemia*,[1] weaves a loose web of silken threads to catch its prey. This genus is to be found hiding in the mud, under the shelter of the stones

[1] See Miall's *Aquatic Insects* for Mr. Taylor's account of *Plectrocnemia*.

in the bed of a swiftly flowing stream. The mud is bound together by silk threads into a large tube, open at both ends, inside of which the larva waits until some small creature gets caught in the irregular web which stretches out for some distance from the tunnel. It then emerges and quickly kills its prey.

The larvae of Caddis-flies are mainly vegetable feeders, and they feed and grow until the winter makes active life impossible to them. They then retire to the pond bottom, into as sheltered a spot as possible, and remain there, probably feeding a little at intervals, until the winter is over, when they become active again, and by late spring or early summer are full grown.

Pupation. Each larva then prepares for its pupation by closing both ends of its case. Some species do this by spinning a silken grating across the open ends, others make a harder, gritty grating, or others again merely fix across some of the same materials of which the case is made.

FIG. 265.—The Pupa of a Caddis. × 4. (After Pictet.)

Within the closed case, in a few days' time, the larva casts its skin piecemeal, and the soft white pupa is exposed; on it can be seen the antennae, quite free from the body, and the legs and folded wings of the imago (Fig. 265). This pupa is peculiar in possessing several organs not found in the imago. There are respiratory hairs on the abdominal segments, and the head bears great toothed mandibles which cross over the face (Fig. 266). The presence of the mandibles is specially interesting, since the imago possesses as a rule no trace of them. They are of distinct use to the pupa, for it is with them that it breaks down the covering at the end of the case, when it is ready to emerge; these mandibles are shed with the pupal skin.

FIG. 266.—The Head of a Caddis pupa, seen from in front.

The pupa retains the power of movement in its abdomen, and thus is able to keep up the current of water which is necessary for respiration.

Emergence of the Imago.

After two or three weeks, the pupa breaks down the end of the case, and—still enveloped in the pupal skin—it swims, back downwards, to the surface of the water, and climbs out into the air by means of some projecting weed, or other object (Plate III., *P*). When at a height of a few inches above the water it stops and rests, then its skin swells and splits, and the new Caddis-fly quickly emerges and flies away—the complete empty pupal skin remaining like a pupal ghost behind.

The imago is at first rather pallid and greenish, but it darkens in colour in a few days; the antennae are thin and tapering, and longer than the body; the legs also are long, but the body is nevertheless usually held rather low down against any support, the drooping wings often hiding the legs.

This is the history of the life lived by most caddises, though a few species differ in some details of their habits. There are certain small caddises which do not actually leave the water before the imago emerges, but merely float to the surface, where the pupal skin is cast and used as a support by the caddis until it can fly away.

Practical Notes on Chapter XXIV.

Caddises form a most interesting subject for study, and they are quite easy to find and to keep through the different stages of their development. They should be brought home from a pond in a tin with only some water-weed in it; they travel better thus than in a jar of water. They need a carefully kept home; any decaying matter in the water soon affects them harmfully. Even the pond forms when in captivity thrive best in moving water; the drip of a tap is sufficient in most cases. Frequently, however, they can be gradually acclimatised to still water.[1] They feed chiefly on water-weed, but seem to relish occasionally a little piece of raw meat. As soon as they have entered the pupal stage, means of exit from the water must be provided, ready for the moment when the pupa swims to the surface in order to enter the air before it casts its skin and emerges as a winged creature. Interesting observations can be made on the construction of new cases by the caddis-worm when it is provided with a variety of materials from which to choose.

[1] I have found this to be the case specially in the genus *Anabolia*.

CHAPTER XXV

INSECTA (*continued*)

Order: Diptera, or Two-winged Flies

General Characteristics. The Diptera are unlike all other insects in having only the front pair of wings. These wings are usually membranous and transparent. Behind them is a pair of very small, club-shaped structures, known as "halteres" or "balancers," which appear to represent the second pair of wings usually present in insects; these halteres are sometimes covered, or partially covered, by a lobe of the front wing called the "squama" (Fig. 267, *s*).

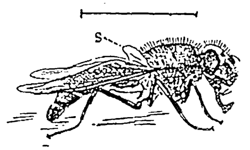


Fig. 267.—A Dipterous Fly (*Syrphus*). *s*, Squama.

The three divisions of the thorax, which are distinct in many insects, are, in Diptera, fused together in one mass, thus giving a firmer support to the muscles of the wings. The head bears a pair of very large compound eyes, usually larger in the male than the female, and also three small simple eyes or ocelli. Placed close together at the top of the head is a pair of antennae which vary considerably in form among the different families of Diptera, and supply one of the characteristics by which they are distinguished. The mouth-parts are modified for piercing and suction, often forming, as in house-flies, a short trunk or proboscis; the homology of the various structures which form it is, however, very uncertain as yet.

The metamorphosis is complete and very striking; the larva in house-flies and blow-flies is a small legless grub known as a maggot, and the pupal stage is remarkable for the dissolution of the whole body of the larva into a structureless,

creamy, or jelly-like mass, from which there gradually develops the form of the pupa and then that of the perfect fly. In aquatic Diptera the larvae are free-swimming and have a more complicated structure.

The abdomen of the imago bears no appendages; the number of segments visible on it varies from four to nine, there being often more visible in the male than in the female, owing to some segments in the latter being indrawn at the end of the body. There may be seven pairs of abdominal spiracles.

Classification. The subdivision of the Diptera into natural families is difficult, and until the group has been more studied it may be well to continue to use the old subdivisions of the order—the *Nemocera* (*nema*, a thread; *keras*, a horn), those with jointed, delicate antennae not ending in a bristle, and with a naked, mummy-like pupa; and the *Brachycera* (*brachus*, short; *keras*, a horn), those with short antennae of usually three joints, the last bearing a bristle either basally or terminally; these latter forms usually also have their pupae enclosed within the last larval skin, which becomes more or less chitinous; within the cases so formed, the body breaks down into a creamy mass, and only after some time does the recognisable pupa develop. The order is a huge one, including already over 40,000 known species, and so each sub-order is again divided into many families, of which only a few can be touched upon here.

Sub-order 1: Brachycera (the Short-horned Flies).

Family 1: Muscidae (House-flies and Blue-bottles or Blow-flies)

The families of the Diptera are very difficult to define concisely, for there are very few characteristics peculiar to any one family, it being rather by a group of characteristics occurring together that they are known. The *Muscidae*,[1] however, nearly always have antennae which are sunk into a concavity on the face, and which have a feathered bristle springing from the base of the terminal joint; "squamae" are present and hide the "halteres."

[1] See *The Book of the Fly*, by G. Hurlstone Hardy. (Heinemann, 2s. 6d.)

Type: **The Common House-fly** (*Musca domestica*).

These flies are only too well known to all, and are justly disliked on account of their habit of feeding on our food and soiling everything on which they settle, a habit more dangerous to us than is generally realised, for flies are now known to be the means of distribution of many poisonous germs.[1] Their irritating buzz is produced by the vibration of their wings. The flies found in houses belong to several different species. *Musca domestica*, which is most abundant in the late summer, can be distinguished by the four black streaks which run longitudinally over the front part of the thorax, and by the single streak along the back of the abdomen. The rest of the body is greyish in hue, except for the base and under side of the abdomen, which are mostly yellow.

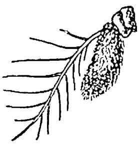


FIG. 268.—Antenna of the House-fly (*Musca domestica*).

The Head. The head bears two large compound eyes, three simple eyes in front, very small but characteristic antennae (Fig. 268) and, below, the peculiarly modified trunk or proboscis. This proboscis is a tube, formed apparently from the labrum and labium, the mandibles and maxillae being absent; hence these flies cannot sting as do those in which these parts are present as needle-like, piercing organs. In front the proboscis bears two small, unjointed palps, and its tip is expanded into two lip-like pads (Fig. 269, *p*), which are traversed by many small canals.[2] When feeding on any solid matter, such as a lump of sugar, saliva is discharged from the mouth and passes down the tube into these canals, and on to the outer surface of the pads. These are then rubbed over the surface of the sugar, which, being dissolved by the saliva, can then be drawn up by the proboscis into the mouth. When

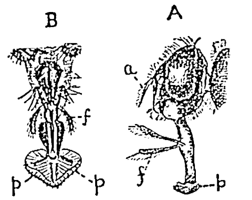


FIG. 269.

A, Head of a fly from the side; *B*, proboscis seen from in front. *a*, antenna; *p*, pads of proboscis; *f*, palps.

[1] See *House Flies and How they Spread Disease*, by C. G. Hewitt, D.Sc. (Cambridge Manuals).

[2] See Schmeil's *Textbook of Zoology*.

not in use, the proboscis is withdrawn, lying in a little hollow on the under side of the head.

The Thorax. As in all the family, the thorax bears only one pair of small membranous wings for flying, and the "halteres" or "balancers," each of the latter being partially covered by a lobe of the front wing, the "squama." Below the thorax are attached the three pairs of hairy, jointed legs, with which the fly may be seen frequently cleaning every part of its body. Each leg ends in a five-

The Foot. jointed tarsus, and the last joint bears two well-developed claws, under each of which is a pad covered with fine hairs. These hairs exude a sticky fluid when the pad is pressed against a flat surface, and this enables the fly to run up slippery window-panes with ease; the pads are first pressed against the pane, causing the hairs to adhere, and are then drawn up again obliquely, so that the attachments of the hairs are snapped one after the other.

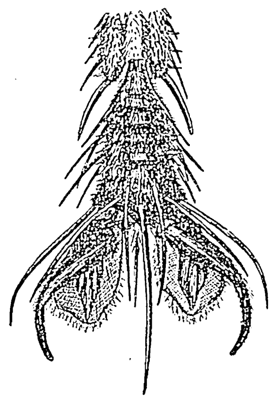


FIG. 270.—The Foot of a Fly.

Life-history. Over a hundred small white eggs are laid by the fly on any damp collection of debris on which the little white, legless maggots can feed when they hatch, which they will do after a day or two. In less than seven days, after two moults, the larva pupates inside the larval skin, which shrinks into an oval, brown, shell-like structure (see Fig. 272 for similar stages in the Blow-fly[1]). Inside this, the curious metamorphosis already described (see p. 367) occurs, and in about a fortnight the perfect fly will emerge, the time taken to complete the metamorphosis varying with the temperature. Many pupae are said, however, to persist through the winter, the flies emerging the following spring. Most of the adult flies die in the autumn, but some seem to hibernate in dark corners, and may become active again any mild day in winter.

[1] Hewitt, *Q.J.M.S.*, 51, 1907, p. 395.

The Blow-fly or Blue-bottle. The Blow-fly (*Calliphora vomitoria*), with its shining blue abdomen, is common everywhere. The long, narrow eggs are laid on meat, perhaps 200 of them together, and the legless maggots, known to anglers as "gentles," bury themselves in the meat, and eat voraciously for four or five days, by which time they are full-grown. Each maggot then burrows in the earth if possible, or retires to the most sheltered corner available, contracts its body to a regular, oval shape, and then, without casting its larval skin, enters the resting stage. The skin hardens and turns brown, forming the "puparium," and the body within undergoes the same curious dissolution as in the House-fly. In four or five days, however, the white pupa is to be found within, and in time this breaks one end of the enclosing cocoon by beating on it with its head; then, pushing off the end as a little cap, the fly emerges; soon its wings expand, its colour darkens, and it flies off to find a mate.

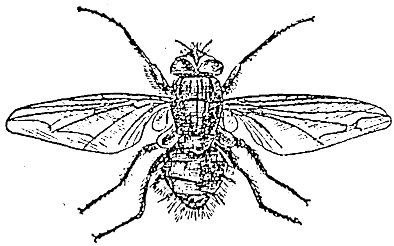


FIG. 271.—The Blow-fly (*Calliphora vomitoria*). (×2.)

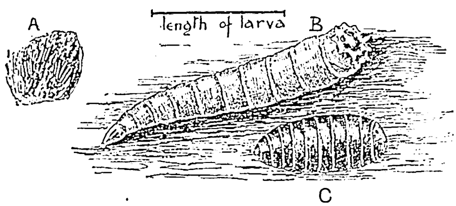


FIG. 272.—Stages in the Life of the Blue-bottle. *A*, Eggs; *B*, larva or maggot; *C*, pupa. (×2.)

The Tsetse-fly. The Tsetse-fly (*Glossina morsitans*), which is such a serious plague in Central and East Africa, is closely allied to the Blow-fly. It pierces the skin and sucks the blood of cattle, and in so doing introduces into the blood of the healthy animal the germs of a disease known as "nagana" or "fly-disease." Where these flies abound, this disease may exterminate whole herds of cattle.

Family 2: SYRPHIDAE (THE HOVER-FLIES)

Hover-fly or Syrphus.

Hover-flies are very plentiful in every garden, where they may be seen hovering over the flowers in the sunshine. With body motionless, and wings vibrating so rapidly as to be almost indistinguishable, they feed on the pollen of the flowers, and then dart rapidly away.

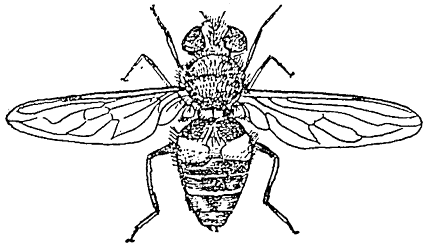


FIG. 273.—A Syrphid Fly, enlarged to show Wing Venation. (× 3.)

They are rather large flies, often hairy, and of a brown colour usually barred with yellow, rather resembling bees or wasps at the first glance, though their thick bodies, with no sign of the remarkably slender "waist" of bees and wasps, very readily distinguish them when more carefully observed. Moreover, the veining of the wings is quite peculiar and characteristic, for at the free edge of the wing are two nervures which run parallel to the edge and are not crossed by any of the longitudinal nervures; just behind these there is a deep bay (Fig. 273).

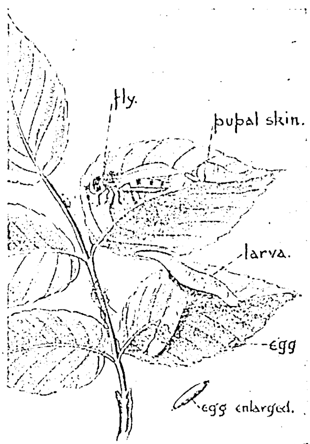


FIG. 274. — *Syrphus seleniticus* (the Hover-fly), showing different stages in its life-history. (Natural size.)

Many of these Hover-flies have larvae which live on plants in the garden, feeding on the green-fly, which they transfix on the three sharp points of their mouth-organs and hold aloft as they feed. They are soft, white, legless grubs, tapering in front (Fig. 274). They constantly stretch and contract their bodies as they creep along after their prey. They pupate on the plants, the larval body contracting and

then separating from its skin, which forms a rather pear-shaped white case round the body, which is transformed within. The fly emerges in about ten days; it is at first small, with tightly crumpled-up wings, but in a quarter of an hour it attains its perfect form.

Volucella. *Volucella* is another common species of Syrphid. It lays its eggs inside the nests of humble-bees or wasps, and it used to be thought that the larva fed on the young bee and wasp larvae. Recent investigations, however, seem to show that this is not so, but that the *Volucella* larvae are useful to their hosts, for they act as scavengers, feeding on the waste matter and dirt of the hive.

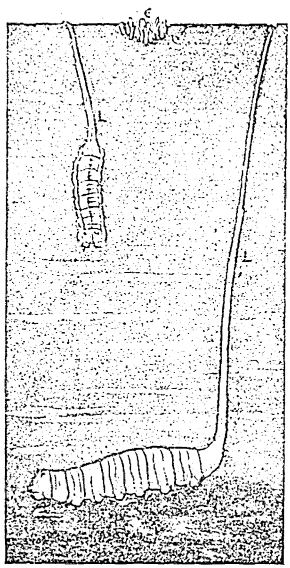


FIG. 275.—*Eristalis tenax.*

E, Eggs; *L*, larvae, "rat-tailed maggots" of two ages, one crawling on the mud, the other suspended from the surface. (Nat. size.)

Eristalis tenax (the Drone-fly). *Eristalis*, another member of the *Syrphidae*, is peculiar in having an aquatic larva of a very interesting and unusual type. This black, hairy "Drone-fly" is rather bee-like in form; it is a strong, active fly, a little over $\frac{1}{2}$ an inch long. It lives on the honey and pollen of flowers, quitting, however, the fresh sunny garden to lay its little packets of white eggs on the surface of the dirtiest, most putrid water it can find, often in a manure tank. The larva, when it hatches out, spends its time creeping over the mud and debris at the bottom, feeding on the decaying organic matter, but always keeping up communication with the air above the water by means of the curious telescopic tail through which it breathes. This stage is a strange contrast to its later life, when it flies freely in a garden, and we are perhaps inclined to think of it as an undesirable inhabitant of our tanks, though, as a matter of fact, it lessens rather than increases the putrid condition of the water by

feeding on the decaying matter in it. The appearance of the larva is shown in Fig. 275. It has a greyish-white, soft body, about $\frac{2}{3}$ of an inch long, with seven pairs of short processes underneath, armed with fine hooks by means of which it crawls along. The head is also soft and rounded, bearing the mouth on its under side; just above this are two very small processes which appear to be sensory. The mouth leads into a peculiar throat which can be dilated, and then acts as a suction pump drawing in the food.[1]

The tail is, however, quite the most conspicuously remarkable structure possessed by the larva, and this organ has earned for it the name of the *Rat-tailed Maggot.* It can be held at any angle to the body, and is capable of great variation in length, so that within limits, whatever the depth of the water, the tail is adjusted so that its tip just reaches the surface; the greatest length attainable seems to be about $4\frac{1}{2}$ or 5 inches, and this is a good deal when the size of the larva is considered. The variation in length is due to the fact that the terminal, dark-coloured, thinner portion of the tail can be withdrawn into the wider, tubular part below, and the latter can itself be also contracted, the whole surface being drawn into transverse wrinkles, until it is only about half an inch long. The tail has at its tip some little recurved bristles which spread out on the surface film of the water, exposing to the air the spiracles connected with the two air-tubes that run side by side down the tail to join the main tracheae of the body (Fig. 276).

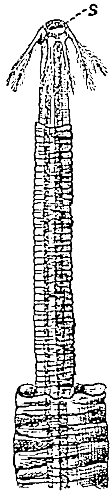


FIG. 276.—The upper end of the Tail of a Drone-fly larva. *S*, Spiracles.

When full-grown the maggot usually leaves the water and enters the earth where this is damp and loose, and there pupates inside its larval skin. The body and tail shorten, two short breathing-tubes grow out on the thorax, the skin turns brownish and hard, and the body within undergoes

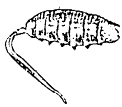


FIG. 277.—The Pupa of a Drone-fly. (Nat. size.)

[1] See the account based on J. J. Wilkinson's investigations given in *Natural History of Aquatic Insects*, by Professor L. C. Miall.

changes similar to those in the Blow-fly. In eight to ten days the cocoon (larval skin) is broken at one end, and the fly emerges.

There are two broods in the year; the flies may emerge in the early spring or in the late summer.

Family 3: STRATIOMYIDAE (THE CHAMELEON-FLIES)

The family of the *Stratiomyidae* is a large and varied one. The flies are usually big and rather bee-like, and from the hind margin of the thorax there project two very small spines which give the name of "Stratiomys" or "Armed fly" to the typical genus. The wings are rather small relatively, and have a simple, but well-marked, nervature.

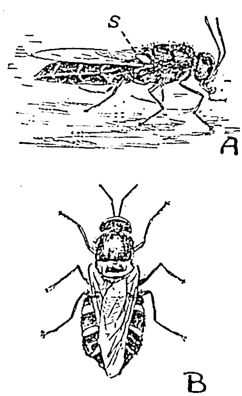


FIG. 278.—The Chameleon-fly (*Stratiomys chamaeleon*). × 2.

A, Side view; *s*, squama; *B*, dorsal view.

The Common Chameleon-fly (*Stratiomys chamaeleon*).

This is a strong, active fly, decidedly bee-like in appearance. The thorax is thick and muscular; the broad and rather flat abdomen is black with yellow markings, and the wings do not reach beyond it. It may often be seen feeding on the nectar of flowers, or near the water preparing to lay its eggs, for in this case again the larvae are aquatic. It has a rapid, short flight, and very often flies off only to return to the same spot. The eggs

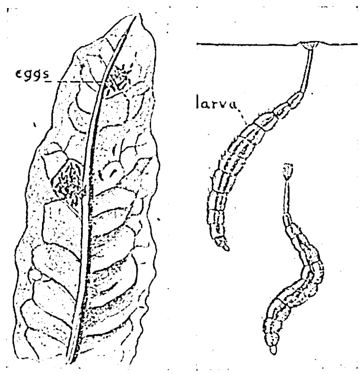


FIG. 279.—*Stratiomys chamaeleon.*

On the left, leaf with eggs; on the right, two larvae, one resting at the surface and one swimming downwards. (Nat. size.)

are narrow, spindle-shaped, and dark brown; they are laid in irregular, overlapping clusters on the under sides of the leaves of some water-plant—frequently the water plantain—which rises a little above the water level in some stagnant pond or ditch (Fig. 279). The little larva when it hatches makes its way rapidly down into the water, apparently pulling itself along by the well-developed pair of appendages on its head (Fig. 280, *p*). When it reaches the water, it floats at the surface, lying at first horizontally, but ultimately taking up a more or less vertical position, head downwards. It is supported in this position by the beautiful circlet of hairs that surrounds the end of the tail. These hairs spread out, forming a little basin filled with air, and the surface tension between the water film and the hairs is sufficient to support the body. Into the little air-basin open the spiracles at the tip of the tail. The larva is at first white and transparent, but when full-grown it is yellowy-brown in colour, and may be 2 inches long. It hangs almost motionless, feeding on the microscopic organisms which pass in the water, driving them into its mouth by the movements of its palps. If alarmed, the larva quickly draws its tail circlet of hairs together, enclosing a little air-bubble in their midst, and dives down into the water with a wriggling movement; there are no traces of limbs or special appendages of any sort to aid in locomotion. On ceasing the attempt to descend, it floats up to the surface again. Although the larva breathes only through its tail, there is a pair of spiracles on each segment of the body except the second and third. These spiracles, however, are not functional in this stage.

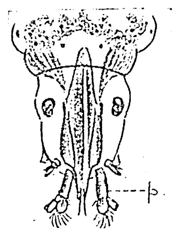


FIG. 280.—The Head of a very young larva of the Chameleon-fly.

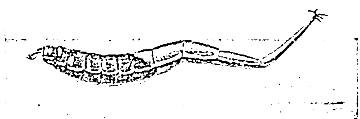


FIG. 281.—The Pupa of *Stratiomys chamaeleon*, floating. (Nat. size.)

The dark body of the fly can be seen in the front part of the otherwise empty skin.

When the time comes for the change to the pupa, the larva may leave the water, or it may remain floating at the

water surface, the body now becoming almost horizontal (Fig. 281).

The larval skin is not cast off, but hardens and remains as a loose case, the pupal body within it only occupying a quite small space at the head end. The pupa is enclosed by a little silken cocoon, and it lies motionless within the larval skin. After a few days the outer skin splits across the thorax, usually just behind the first segment, and then down the middle line for two segments and across the fourth segment of the body, the big fly pushing open, as it escapes, the little "cupboard doors" so formed. In spite of its heavy body, the fly is able to stand on the surface film of the water, and its hairiness prevents it from getting wet as it emerges. After a short while the wings unfold and stiffen, and then it flies away. The eyes of this fly when first it emerges are wonderful to see in their brilliancy.

Practical Notes on Diptera Brachycera

1. Study the flies to be seen about the house, and try to distinguish the different species which are most common.[1]

2. Obtain a little "fly-blown" meat and watch the development of the *Blow-fly*. Keep a record of development, and sketch all stages.

3. Search the leaves of rose-trees, limes, sycamores, or any plants infected with *Aphides* for the larvae of the *Hover-fly*. Separate one and test its efficiency as an Aphis destroyer. Keep it until it pupates and the fly emerges, making notes on the development. Watch the flies in the garden hovering over the flowers, and learn to distinguish them by their flight and colouring.

4. Obtain some *Drone-fly* eggs or larvae from a manure-tank or dirty rain-water tub, and keep them in a wide shallow jar of rain-water, with plenty of decaying vegetation at the bottom. Watch the movements of the "Rat-tailed maggots" which hatch from the eggs, drawing them to scale. Put one first in shallow water, then add water to the vessel, and note the extension of the tail, and sketch again to scale. Put the full-grown larva into a shallow dish, with an earth bank rising above the water at one side, and note the date of pupation and later the date of the emergence of the fly. Make notes on the appearance and structure of the fly.

[1] See Prof. Miall's *House, Garden, and Field*, chap. xix.

5. Look for the eggs of the *Chameleon-fly* on the leaves of water-plants which rise above the level of the water; keep them carefully in a similar position in your aquarium, and as soon as they hatch, study the movements of the larvae. Follow the whole life-history, making a series of illustrative sketches.

CHAPTER XXVI

INSECTA (*continued*)

Order: Diptera (*continued*)

Sub-order 2: Nemocera (Thread-horned flies).

Besides the types of Diptera described in the previous chapter—in all of which the perfect insect was a thick-bodied fly, more or less resembling a blue-bottle fly in general form—there are others which resemble, instead, a gnat or midge, having long, slender legs and long, narrow, usually hairy wings; also they possess the many-jointed, long antennae which give the name of *Nemocera* to this sub-order (see p. 367).

Here again many families are included.

Family 1: Culicidae (Gnats, Mosquitoes, etc.)

The *Culicidae* are characterised by their long, projecting proboscis, and by their plumed antennae.

Type: **The Common Grey Gnat** (*Culex pipiens*).

These buzzing, irritating little creatures, with their annoying sting, are perhaps only too familiar to us in their winged state, and it may be that we approach the study of their life-history without much pleasurable anticipation; but we are rewarded by the discovery of a story of unexpected interest, displaying at every stage curious modifications of structure and of habit to suit the changeful life they lead.

Imago. The form of the winged imago is shown in Fig. 282. The male can be at once distinguished from the female by his very bushy antennae and much longer palps;

also he does not usually sting and draw blood from a living prey as does his mate, but lives a harmless life, sipping the nectar of flowers.

Correlated with this difference in food and habit, we find a difference in the mouth-parts of the sexes. In the female, the lower lip or labium is much elongated, and is soft and deeply grooved, forming a trough in which lie five very sharply pointed, almost thread-like rods (Fig. 283). The

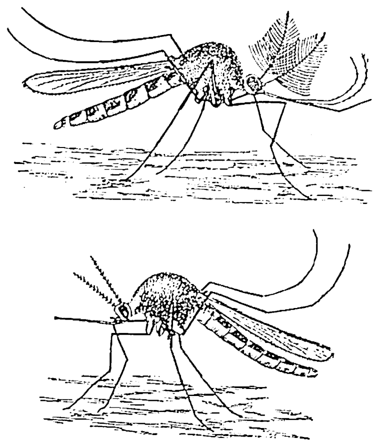


FIG. 282.—The Common Grey Gnat (*Culex pipiens*), in characteristic attitudes when at rest.

The male above, the female below. The actual length of body is ⅙ of an inch.

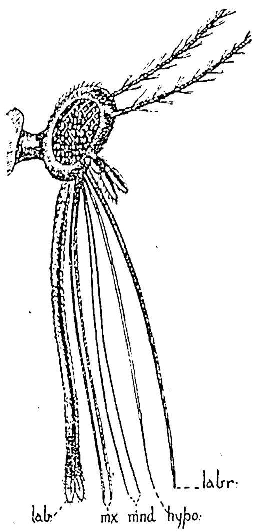


FIG. 283.—Head of a Female Gnat, with the mouth-parts artificially separated in order to show them all.

lab, Labium ; *labr*, labrum ; *mx*, maxillae ; *mnd*, mandibles ; *hypo*, hypopharynx.

two finest of these correspond to the mandibles (Fig. 283, *mnd*), and the two slightly coarser rods, which have serrated tips, to the maxillae (Fig. 283, *mx*), whilst the fifth, unpaired rod is an outgrowth of the roof of the mouth, not found in other insects, and called technically the "hypopharynx," Fig. 283, *hypo*). The labial trough is closed above by the upper lip or labrum, which is also long and slightly grooved, and thus forms with the labium a flexible tube.

The tip of the labium ends in two little fleshy lobes which are pressed firmly on to the skin of her victim, as the gnat prepares to bite; the lancets are forced into the flesh, being kept steady by the terminal

part of the lower lip, though higher up this separates from the lancets and bends backwards as they enter the skin, and so the distance between this and the gnat's head is lessened.

The blood is drawn up by the suction caused by the dilatation of part of the oesophagus. The gnat not only pierces the skin and sucks up the blood of its victim, but is said also to inject into the wound a poisonous fluid which causes irritation and inflammation; no poison-gland, however, has yet been demonstrated.

The male gnat has a similar proboscis, but it contains two pairs of simple, unserrated lancets only; also there is no similar power of suction in the oesophagus, and it is doubtful whether he ever stings.

A Gnat's "Buzz." The buzzing of a gnat is caused in two ways: the deeper notes, by the vibration of the wings in flying; the shriller notes, by the vibration of minute, stiff membranes, placed just behind the spiracles, which occur in a row down each side of the body. The shrill buzzing seems to be confined to the female gnat, and serves to attract the males; their bushy antennae have been shown to be thrown, by this special pitch of note, into sympathetic vibration, and swarms of them can be attracted by sounding this note artificially.

The Eggs. After mating, the female fly makes her way to water, in a ditch or rain-water tub perhaps, and there she lays her eggs on the surface, two or three hundred of them. As they are laid, she arranges them with her hind legs and glues them together, side by side, making a little floating "raft" of eggs (Fig. 284); these are all pointed at their upper end, and between the points a bubble of air is securely held, so that, if the raft is submerged or upset, it always floats to the surface and rights itself again. This is of importance, since the eggs require plenty of air for their development. After two or three days, the eggs hatch, the lower end of each separating off neatly as a little hinged lid (Fig. 285).

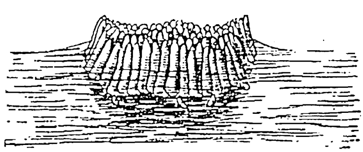


FIG. 284.—The Gnat (*Culex pipiens*). Raft of Eggs floating in the water. (× 4.)

The Larva. From each egg emerges a small transparent larva, which at once begins to swim actively through the water, with the rapid contortions of body which have earned it the name of "wriggler," by which it is known to children.

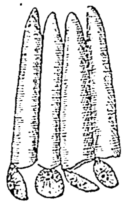


FIG. 285.—*Culex pipiens.* Four eggs enlarged and with open ends, the larvae having hatched from them. (×12.)

The larva, though able to swim so rapidly, when undisturbed will remain for a long time floating motionless, in a vertical position, head downwards, at the surface of the water (Fig. 286), and its structure can then be well seen with the aid of a hand lens.

The head, thorax, and segmented abdomen are all distinct, but there are no paired appendages at all, except on the head. The mouth has on either side of it an appendage beset with hairs. By the constant motion of these, water, together with any microscopic organisms it may contain, is driven into the mouth, and thus food is obtained. (Compare the Chameleon-fly larva, p. 375.)

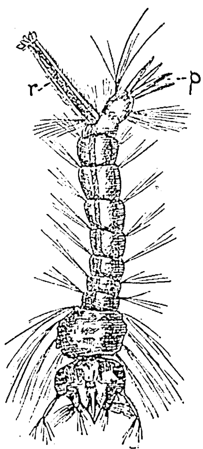


FIG. 286.—Larva of *Culex pipiens.* (×16.)

r, Respiratory tube; *p*, swimming organ.

Respiration in the Larva. From the eighth segment of the abdomen there projects obliquely upwards to the surface of the water a little tube (Fig. 286, *r*), which terminates in five small valves. These spread out at the surface into an air-containing basin, just as does the circlet of hairs of the Chameleon-fly larva, and here also they enable the larva to hang motionless from the surface film, with its heavy head downwards, taking in a fresh supply of air through the spiracle at the end of the tube. This spiracle is in communication with the two great tracheae of the body, which can be clearly seen through the transparent skin.

Movements of Larva. When the larva is about to leave the surface, the valves close over the spiracle, and, being no

longer held up by the surface tension on them, the larva sinks to the bottom. In rising again, it jerks its whole body, and also uses the special swimming organ which projects laterally from the last segment of the tail, ending in four lobes, and bearing at one side a plate of stiff bristles which possibly serve as a rudder to guide the movement through the water.

The Pupa. In two or three weeks, the larva moults its skin for the third or fourth time, and at this last moult it changes its shape completely and becomes a *pupa.* It now floats head uppermost, and the rudiments of the eyes, wings, and appendages are clearly visible through the pupal skin which covers the big, rounded mass at the front end. The abdomen is little changed, except that to the eighth segment is attached only a single pair of "tail-flaps," which are used in swimming; for this pupa, though it does not feed, is not always quiescent like most other insect pupae. If touched, it at once darts down in the water, only to rise to the surface again as soon as it stops struggling. Since the head-end is now uppermost, we find that the pupa breathes through two little trumpet-shaped tubes on its head, the tail tube being entirely absent. The inner surface of these "trumpets" is hairy, and so water is prevented from entering them.

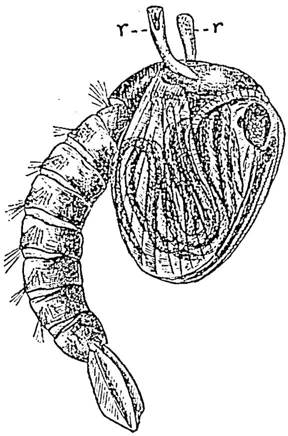


FIG. 287.—Pupa of the Common Gnat (*Culex pipiens*). (×12.) *r*, Respiratory tubes.

Emergence of Imago. Finally, when the body of the imago has been perfected within, the skin splits along the back between the two air trumpets, and the perfect insect begins to emerge. The head and thorax push up first into the air, and then the legs and wings are carefully withdrawn.

The few moments before the tips of the legs are free are the most critical in the life of the gnat, for the top-heavy body is supported merely by the frail bark made of the pupal skin, and the least breath of air sends it scudding across the

water, and may upset it and drown the fly. However, when once the legs are free this danger is over, for they immediately spread out on all sides of the old skin on the surface film of the water, making the equilibrium of the body stable once more, and so the insect can rest secure until strong enough to fly away and fulfil her destiny.

The Spotted Gnat or Mosquito (*Anopheles maculipennis*).

The Spotted Gnat also occurs in Britain, and is widespread in warmer countries. It can be recognised by the four dark spots on each wing; also, when at rest, it does not hold its back legs so high in the air as does the common gnat, and its body is straighter. This is the gnat which is responsible for the malaria of South European and tropical countries. The disease is due to a microscopic germ in the red blood-corpuscles of man, and the gnat, passing from one victim to another, and drawing blood from each, carries the infection and thus spreads the disease.[1]

The *eggs* of the Spotted Gnat can be recognised by the fact that they are not laid in a raft-like mass, but are spindle-shaped, and lie separately and horizontally on the water, supported by two little lateral air-sacs like small blisters.

The *larvae* also lie horizontally on the surface, supported by five pairs of small, stellate hairs on the back of the abdomen; they have a very short, dorsal prominence on the eighth abdominal segment, which bears two spiracles. From the end of the tail projects an unpaired row of stiff hairs and three tufts of hairs.

The *pupae* are very similar to those of *Culex*, but are green.

The Phantom-fly (*Corethra plumicornis*).

Corethra is another member of the Culicidae. It is better known perhaps in its larval than in its winged state, for its curious transparent "phantom larva," when once seen, cannot but arouse interest.

The Imago. The winged insect closely resembles a gnat, and the male has similar conspicuous, plumed antennae, whilst in the female they are small.

[1] See *Mosquitoes and their Relation to Disease* (British Museum *Economic Pamphlet*, No. 4, price 4d.).

The *eggs* are laid on the surface of a fairly clean pond in a flat sheet of jelly, in which they lie in spiral lines.

The Larva. The larva (Fig. 288) grows to about half an inch in length, and is transparent for the most part, so that when motionless it is quite difficult to distinguish, the only noticeable parts of the body being the dark compound

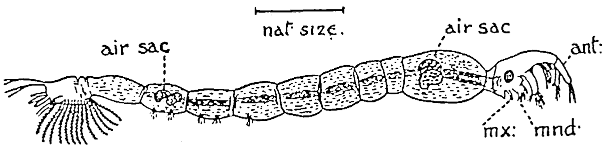


FIG. 288.—*Corethra plumicornis* (the "Phantom larva").
mnd, Mandible; *mx*, maxilla; *ant*, antennae.

eye-spots on the head, and the air-sacs with their dark pigment on the thorax and on the seventh abdominal segment. When disturbed, the larva moves with great rapidity, flicking its tail, and then quickly becoming once more motionless. The movement is aided by the vertical fin of stiff, plumed hairs which is attached below the tail segment of the body, and corresponds to the vertical fin in the gnat larva.

Food of Larva. This "phantom" feeds on any minute larvae or crustaceans in the water, seizing them with its antennae, which are modified for this prehensile function, and then crushing them and passing them into the mouth with its strong toothed mandibles, the maxillae and labium also helping in the process.

Professor Miall tells us that this solid food passes into the mouth but no further, the back of the mouth being closed by a fringe of stiff hairs. The food, therefore, is dissolved by the secretions of the mouth, and only the liquid portion passes on into the stomach, the insoluble particles being expelled from the mouth by the eversion of the pharynx.

Respiration of Larva. Respiration seems to take place through the whole surface of the body, for there are no spiracles. The two pairs of *air-sacs*, which are enlargements of the two air-tubes of the body, alone, of all the tracheal system, contain air; their surface is marked by spots of black pigment, which, it is suggested, may have something to do with the chemical process by which these

air-sacs, empty in the young larva, are filled later. Doubtless the sacs function as floats to support the body.

The Pupa. The change to the pupal condition is accompanied by a change in position as well as an alteration in shape.

The head-end swells up, as in gnats, into a large, rounded mass, in which the compound eyes, antennae, legs, and wings of the adult can be distinctly seen. The abdomen remains long and segmented, but terminates now in two pairs of delicate tail flaps (Fig. 289, *a*), which, as in the gnat pupa, can be used in swimming if the pupa is disturbed. The movement is a quaint one to watch, for it is very sudden and in a vertical direction downwards, giving the pupa the appearance of making a series of rapid curtseys. If undisturbed the pupa floats head uppermost, either at the surface or a little way below. From its head-mass there projects a pair of breathing-tubes which can make communication with the air above the water.

From this pupa the imago emerges much in the same way as in the gnat.

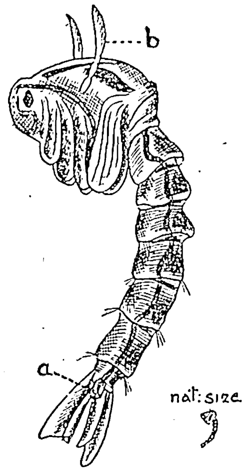


FIG. 289.—*Corethra plumicornis.* (Pupa.)

a, Tail appendages for swimming; *b*, breathing-tubes.

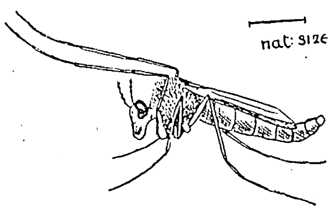


FIG. 290.—The Harlequin-fly (*Chironomus*) ♀, in characteristic resting attitude with the front legs raised and projecting above the head.

Family 2: CHIRONOMIDAE (MIDGES)

The members of this family are very gnat-like in form, but they have no projecting mouth-tube or proboscis and no piercing or sucking mouth-parts. The winged insect probably never feeds. Further, when at rest these midges raise the front legs, using them as

feelers, whilst the true gnats rest usually with their hind legs raised. Here, as in true gnats, the males have bushy antennae, whilst in the females they are scanty and thin.

Type: The Harlequin-fly (*Chironomus*).

The Harlequin-fly is usually mistaken for a gnat, but it is really quite a harmless midge that cannot sting. On the window-pane it can easily be distinguished from a gnat by noting its characteristic attitude (compare Figs. 290 and 282). Like a gnat, the Harlequin seeks water when about to lay her eggs.

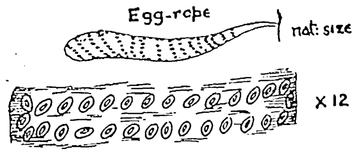


FIG. 291.—Eggs of *Chironomus*.
Upper diagram, egg-rope entire; lower diagram, a small piece cut across and drawn to show the regular arrangement of the eggs.

Eggs. The eggs are laid in a gelatinous rope, sometimes nearly an inch long, which is moored at one end to some object, frequently to the side of the rain-water tub in which the eggs are so often to be found.

The Larvae. The larvae are bright red in colour, and are usually known as *blood-worms*. They may be an inch long when full grown, and they swim very rapidly in the water, contorting their bodies into loops, and even figures of eight, as they move, and so earning the name of "Harlequins." Although they are very frequently to be seen swimming freely in the water, especially at night, normally they make for themselves little, nearly vertical tubes of earth, either at the water bottom, or on the side of the vessel they are in, sticking the particles together with a silky, salivary secretion from the mouth. In this tube they shelter, holding on to their cases probably with the hooked lobes at the end of the body.

Their food consists of vegetable matter or of particles of organic substance in the soil which they swallow, and which often makes the whole intestine appear dark through the transparent skin (Fig. 292). On the head are two short antennae, and, round the mouth, mandibles and rudimentary maxillae.

On the segment just behind the head, and also on the last

abdominal segment, is a pair of small lobed processes set with minute hooks which aid the larva in moving along its mud burrow.

Respiration is of special importance to a larva living below the surface in dirty and stagnant water, as the Harlequin larva does. The gnat larva in the same tub or pool must come to the surface frequently to breathe, but the "blood-worm" can stay below for many hours, though at times it seems that it is necessary for it to leave its mud-tube and swim about near the surface in order to take in oxygen from the purer, better aerated surface water, through the long gill tubes filled with blood, which project from the last segment but one of the body, and probably also through the much smaller but similar processes on the last segment (Fig. 292). The blood is red because of the presence in it of haemoglobin, which doubtless acts here, as it does in higher animals, as an oxygen-carrier, very readily combining with the oxygen in the water and carrying it in the blood to all parts of the body. The circulation of the blood is caused by the action of the tubular heart which may be seen pulsating near the hinder end of the body on the dorsal side.

It is to be noted that there is no functional tracheal system in this larva; the air-tubes that are present are rudimentary and closed.

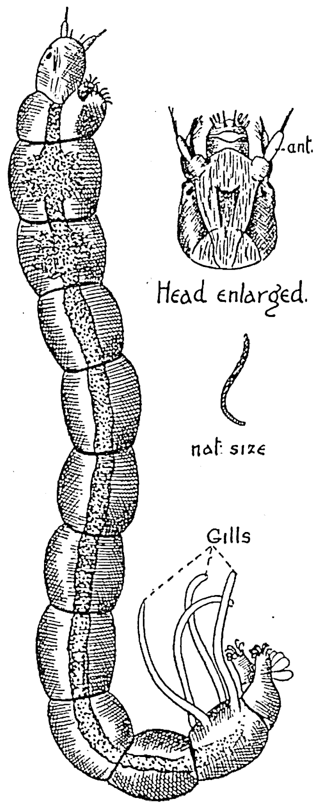


FIG. 292.—*Chironomus* Larva.

The Pupa. When the larval life is complete, the last larval skin is shed and the pupa appears, at first lying half out of the mud-tube, and then, after a day or two, floating

up to the surface. It has a thickened head-end in which the organs of the adult can be seen packed away below the pupal skin (Fig. 293). There is a long, segmented abdomen, the last segment bearing a pair of processes, each fringed with long, stiff hairs which aid in the locomotion of the pupa.

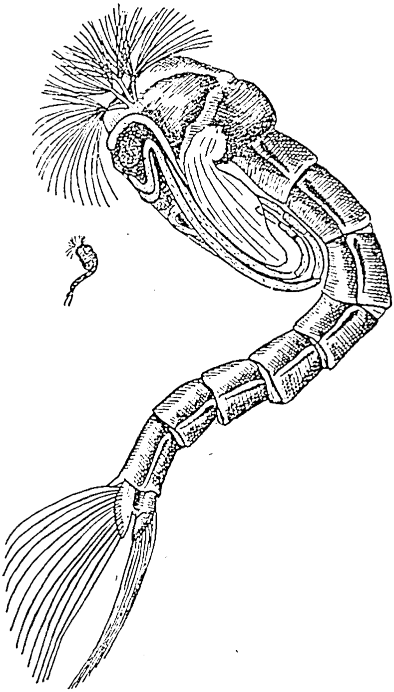


FIG. 293.—Pupa of *Chironomus*.
(Its real size is shown in the small figure.)

Respiration takes place through two conspicuous bunches of fine white hairs which project upwards from the front of the thorax. These are tracheal gills, not blood gills like those on the abdomen of the larva. The pupa may swim in the water, though it usually rests motionless at the surface. In time the pupal skin splits, and after a very brief pause, of a few seconds only, the perfect Harlequin-fly rises into the air.

[1] For a full, detailed account of *Chironomus* see *The Harlequin Fly*, by Miall and Hammond.

The "Splay-footed" Fly[1] (*Tanypus*).

The Larva. Another frequent inmate of the same rain-water tub as the larvae of the Gnat and the Harlequin, is the *Tanypus* larva, a small, yellow-brown, thread-like creature which swims actively through the water with serpentine bends, but without the complicated twists of a Harlequin. Like the latter, this larva makes mud-tubes, but it leaves them very frequently. The head bears a pair of antennae that can be completely withdrawn within it. The first segment of the body bears a pair of hooked structures fused at the base, and the last segment bears a similar pair, but larger and widely separate in this case; in all these, the circlet of hooks can be withdrawn within the soft flesh. In swimming the hind appendages move with a quite regular stroke, their tips and the hooks being first indrawn and then suddenly shot out again, separating as widely as possible. The fused appendages in the first segment are used chiefly when moving over a surface, when the whole body seems to be pulled and hitched forward on them as on a kind of crutch. The last segment bears four little gills and two other processes, each having on it a bunch of stiff hairs.

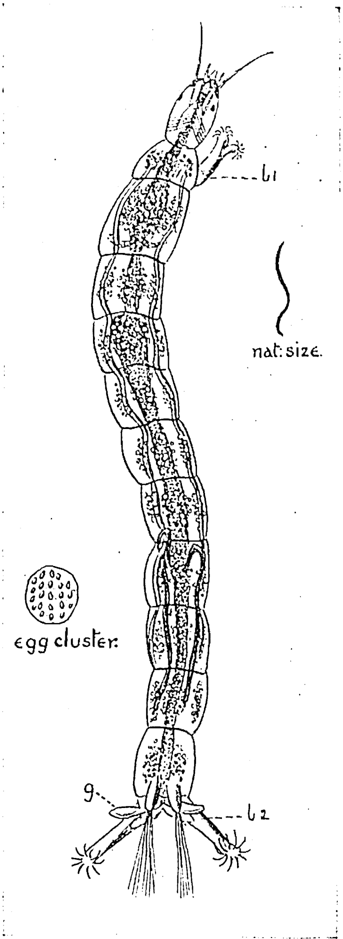


FIG. 294.—*Tanypus* (larva). l_1, Fused front appendages; l_2, swimming appendages; g, gills. Egg cluster is ×2.

[1] The name refers to the peculiar appendages of the larva.

The Pupa. The pupa also is aquatic, and resembles that of gnats, having much the same shape, and a similar pair of respiratory tubes on the thorax. It is, however, of a

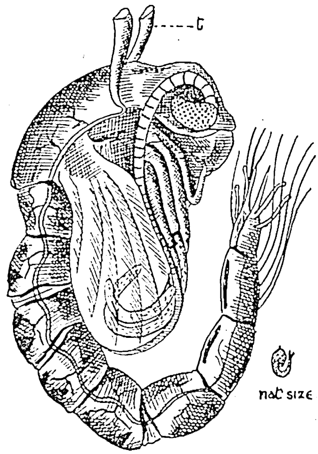


FIG. 295.—*Tanypus* (pupa). *t*, Respiratory tubes.

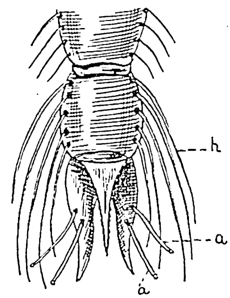


FIG. 296.—*Tanypus.* Tail segments enlarged to show the stiff hairs, *h*, and also the tubular sucker hairs, *a*.

paler, yellow-brown colour; also it generally rests below the water, apparently fixing itself by the sucker-like tips of four special, tubular hairs present on the last segment of the abdomen (Fig. 296, *a*). It seems able either to suspend itself by these in the position shown in Fig. 295, or it will lie at the bottom of the water with the hairs fixed and the thorax bent right over the abdomen. Occasionally, it will suddenly straighten the body and throw back the head and thorax for a brief moment, but except for this movement, it will hang or lie motionless for hours.[1]

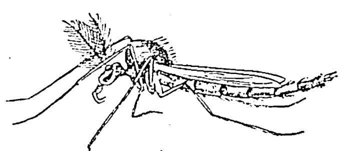


FIG. 297.—*Tanypus* (imago).

Imago. From this pupa, after a few days, the fly emerges at the surface of the water, and soon the female deposits on some floating object a little, flat, circular

[1] I was unable in my specimens to see the abdominal suckers referred to by Professor Miall (*Aquatic Insects*, p. 154) and J. Meinert.

mass of jelly, in which are embedded a number of long, oval eggs, arranged in definite rows, which hatch out in due time.

The Horn-bearing Fly (*Ceratopogon bicolor*).

The Larva. *Ceratopogon*, like *Tanypus*, will probably first come under our notice in the larval form, for the larva is very common on the surface of stagnant ponds where there is a plentiful supply of small, filamentous Algae. The larva has a very slender, rather transparent, thread-like body, which, when touched, immediately becomes rigid; it may be half an inch long. The head is small, and bears four tiny, very black eyes, and a pair of strongly incurved, black mandibles. There are twelve segments to the body, and the last one bears a circle of black bristles which can be moved forwards or backwards. Right at the tip are also five little transparent processes which can be protruded or withdrawn; these are probably gills. The whole surface of the body is striated with fine longitudinal lines. A pair of air-tubes can be seen through the transparent skin. The larva swims like an eel through the water, with a very rapid motion.

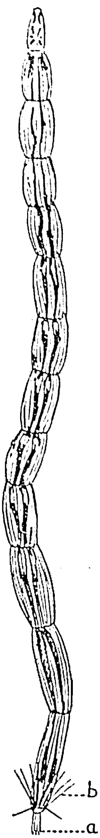


FIG. 298. *Ceratopogon bicolor* (larva). (Much enlarged.) *a*, Gills?; *b*, stiff hairs.

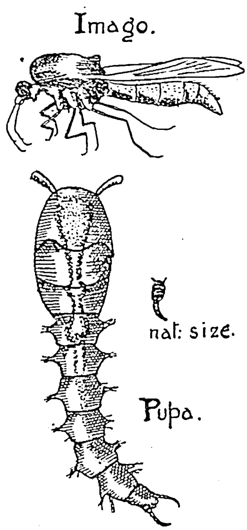


FIG. 299.—Imago and Pupa of *Ceratopogon*.

The Pupa. In due time the last larval skin is thrown off, and the pupa appears at the surface, where it hangs

vertically or slightly curved, never curled up like the Gnat or *Tanypus* pupae. It has two respiratory tubes at the upper end, and on the last segment a pair of spines with which it is said to be able to fix itself to floating objects.

The Imago. From the pupa emerges a fly with a humped thorax bearing a little horn-like projection behind, and a pair of transparent, naked wings which are laid horizontally over the body when at rest (Fig. 299). The eggs are laid in star-shaped clusters of a hundred or more amongst the floating vegetation of the pond.

Most of the other species of *Ceratopogon* are not aquatic in the larval state, but are terrestrial, living under the bark of trees. These forms have flies with hairy wings; many of them are annoying little creatures, with a most irritating sting; *Ceratopogon varius* of Scotland is one of these pests.

Family 3 : Simuliidae (Sand-flies or Buffalo-gnats)

Sand-flies are little, dark-coloured flies with a humped thorax, short, straight antennae, no projecting proboscis, rather short legs, and broad, long wings.

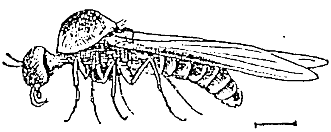


Fig. 300.—*Simulium*, the Sand-fly.

The River Sand-fly (*Simulium*).

These flies often congregate in numbers on the bushes near a swiftly running stream, feeding, it is said, on the juices of leaves, or on the honey-dew given out by *Aphides*. The female is said to suck human blood, and in so doing to introduce the germ of the disease known as "Pellagra," a disease very rare in England, but found in parts of Scotland, and rampant in some regions of the world.[1] The eggs are laid in jelly-like masses attached to the water-plants growing close to the water or at its surface, and soon there will be

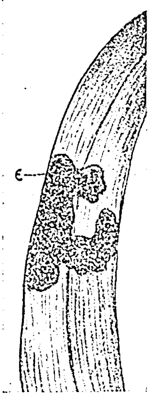


Fig. 301.

e, The eggs of *Simulium* on a water-plant. (Nat. size.)

[1] See *Insects and Man*, by C. A. Ealand.

hundreds of the strange little black larvae clinging to the under side of the leaves wherever the current of water is swiftest.

The Larva.

The larva has a segmented body which is thinnest in the centre. The swollen hind end bears a median structure said to be formed of two fused appendages, and bearing concentric rows of hooks (Fig. 302, *A*) which, together with the three sucker-like projections from the end of the body, enable the larva to keep firmly fixed, even in a strong current. On the first thoracic segment also, there is a single, finger-like process beset terminally with hooks, formed from two fused appendages. By means of these appendages at the two ends of the body, the larva creeps about fairly actively, moving in a leech-like way, fixing the front of the body, and then drawing up the hind end and fixing that, before throwing the front end forward again. The head bears the most remarkable organs of the larva, two plume-like structures, each formed of many long filaments which are constantly in motion driving food into the mouth. These plumes are immediately folded together and withdrawn if the larva is startled, and only gradually unfolded again. If picked up and dropped into the water, the larva falls, but in so doing spins a thread, so fine as to be almost invisible. Having reached the bottom, it

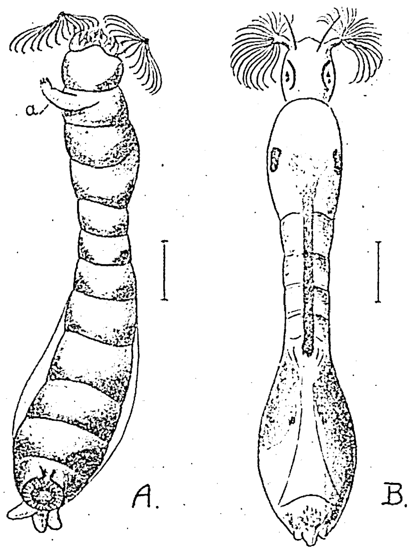


FIG. 302.—The Larva of *Simulium*.
A, Ventral view; *a*, fused anterior appendages; *B*, dorsal view.

climbs up again by this thread, holding it between the thoracic appendage and the mouth. Professor Miall has found that in their native streams, if alarmed in any way, these larvae at once drop on such a thread from their support, and climb up it again to their original position when the danger is past. Sometimes a whole network of such threads surrounds them. When the larva is full grown it is about half an inch long, and two dark spots become visible on the thorax (Fig. 302, *B*)—a sign that pupation is about to occur.

The Pupa. At this time the larva spins a little oval-shaped nest or cocoon, attaching the silk threads on each side to a leaf, and inside this the larval skin is thrown off.

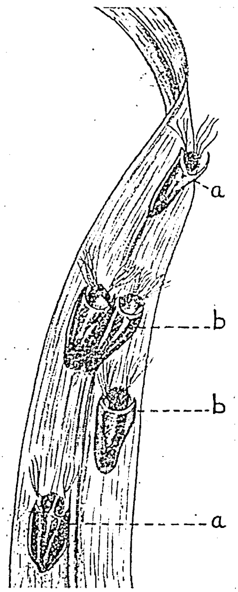


FIG. 303.—Pupae of two species of *Simulium* (× 2).

a, Pupal cocoon with a central projection from the upper margin of the pocket; *b*, cocoon of *Simulium sericeum*: the pupa has four two-branched gill-filaments on each side, and the cocoon is without a central spike.

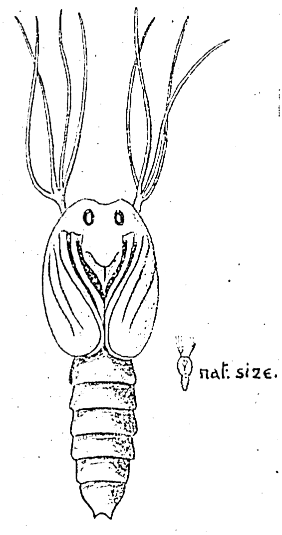


FIG. 304.—Pupa of *Simulium* removed from the cocoon.

The pupa retains considerable power of movement, and it breaks away one end of the cocoon, so that it finally lies supported in a silken pocket, but with its head-end and branched

respiratory filaments projecting into the current of water (Fig. 303). The pupae in the pockets with a central spike on the margin are like those shown in Fig. 304, having four unbranched filaments on each side, whilst those in the pockets with simple margin have four two-branched hairs on each side. The pupae are constantly changing their positions inside the pockets, jerking themselves round so that they expose first one side and then another. The two commonest species are *Simulium sericeum* and *Simulium elegans*.

Emergence of Imago.

This pupa is always submerged, and yet the fly which is to emerge from it would be injured if wetted by water. It is very difficult to observe the process by which this danger is surmounted. Apparently, during the latter part of the pupal stage, which lasts about two weeks, air collects under the pupal skin, so that when this splits, the imago rises with this air-bubble, which is extended in an air-film clinging to the hairs on the surface of the body of the fly, and thus all danger of drowning is avoided.[1]

Family 4 : TIPULIDAE (DADDY-LONG-LEGS OR CRANE-FLIES)

The *Tipulidae* are Diptera with slender bodies, very long legs, and narrow wings, which are held well above the body when at rest, the second pair of modified wings or halteres being unusually large. The veining of the wings is also characteristic and is rather complex, especially near the free tips of the wings (Fig. 305).

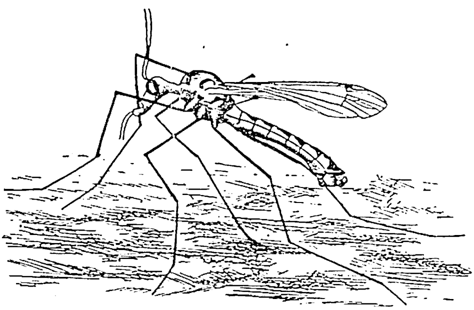


FIG. 305.—The Spotted Crane-fly, male (× 2).

The Crane-fly or Daddy-long-legs.

This insect is shown in Fig. 305,

[1] I have never been lucky enough to see the imago emerge, though I have reared many. These statements are based on Verdat's observations, quoted by Prof. Miall in *Natural History of Aquatic Insects*, p. 373.

where the typical form of body, the narrow wings, large halteres, long legs, simple, long antennae, and projecting palps with their characteristic long terminal joint, all are clearly visible.

In all species of Crane-flies, the sexes can be distinguished by the shape of the end of the body. In the male this is much thickened and blunt, whilst in the female the slender abdomen is terminated by two pairs of pointed appendages which are used in egg-laying.

The Eggs. When the eggs are to be deposited, the female fly descends, usually amongst grass stems, and standing on her last pair of legs, with her body in a vertical position, she lays the eggs one by one, dropping them on the surface and pushing them into the ground with the two pairs of appendages which hold the egg and form the ovipositor. Each time the insect settles she lays a few eggs, depositing altogether from 200 to 300 before she has finished.

The Larvae. The larvae live entirely underground, feeding on the roots of grasses as well as on dead vegetable matter; they often do much damage in corn-fields, and are known to farmers as "leather-jackets," owing to the toughness of their skins. The mouth has two strong, toothed mandibles and a toothed labrum, against which the mandibles work. The palps are short and the maxillae rudimentary. These parts are difficult to see at first in a specimen under examination, as the head segment is then telescoped within the next, but if gently pressed, the head will be everted and the feelers and mandibles become visible. The larva may grow to an inch in length. It is earth-coloured, and not easy to detect quickly. At the tail-end of the segmented body are some small, sharply pointed, stiff processes and some fleshy lobes surrounding two terminal spiracles.

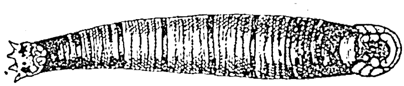


FIG. 306.—Larva of *Tipula* (× 3). (A "leather-jacket.")

The head segments are telescoped in on the right.

The Pupa. The larvae which are hatched out in the spring pupate and give rise to winged Crane-flies in the same summer. From the eggs laid by these arises a second

brood of larvae which hibernate throughout the winter, only pupating the following spring. After the last larval skin has been shed, the pupa, which is then disclosed, assumes a vertical position, and gradually works its way up to the surface of the ground, projecting its head above the surface shortly before the fly emerges. Sometimes numbers of these pupae are to be seen in this position within a few square yards of grass land. They are enabled to move upwards in this way by the spines which project from all the abdominal segments, and which are specially numerous near the end of the body; these keep the pupa from slipping backwards.

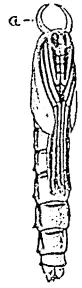


FIG. 307.
Pupa of *Tipula*.
(× 2.)
a, Respiratory horns.

The pupa here, as in gnats and midges, bears on its head two little respiratory horns.

When the fly is ready, it escapes through a split along the dorsal exposed part of the thorax of the pupa, and flies off with the two fore-legs extending forwards and the four hind-legs stretched out behind.

Tipula oleracea is perhaps the commonest Crane-fly. It is to be seen in numbers especially in August and September.

The Spotted Crane-fly (*Pachyura maculosa*) is also very abundant, more particularly in gardens. It can be distinguished by its yellow body marked with darker spots.

These Crane-flies would rapidly become a serious pest if it were not that their numbers are kept in check by rooks, starlings, peewits, and other birds that feed on them.

Family 5: CECIDOMYIDAE (GALL-MIDGES)

One other family of small, insignificant flies belonging to the Diptera Nemocera is worthy of mention, because of the fairly common galls produced by their larvae on different plants. These are known as the Gall-midges or Gall-gnats.

The flies are minute, and often brightly coloured. They have rather broad wings with very few nervures on them. The antennae are relatively long and hairy. The female has a long ovipositor with which she places her eggs in the tissues of the chosen plant, and around the larva arises a Gall.

The Hessian Fly (*Cecidomyia destructor*), which sometimes does great damage in corn-fields, is one of these Gall-midges.

Another (*Cecidomyia taxi*) forms a gall at the end of a yew twig, causing the leaves to be clustered in a little bunch (Fig. 308), inside of which is usually one larva only. The gall-midge emerges in June.

Another species forms a hairy, tubular gall standing on the upper side of the leaf of ground-ivy; another, a white, pimple-like, hairy gall on the under side of the leaf of meadow-sweet; another causes a swelling on the woody twig of the sallow willow; and there are, besides these, many other gall-forming species.

FIG. 308.—Gall ("*a*") on Yew, caused by *Cecidomyia taxi.*

Sub-order 3: Aphaniptera or Fleas.

Fleas are sometimes considered as peculiarly modified Diptera, though they are also sometimes placed in a special order because of the many points in which they differ from Diptera and from any other order of insects.

They are always wingless, and are very compressed laterally. The head is relatively small, and the first pair of legs is turned forward in such a way that they appear as if growing from the head. The mouth-parts are peculiar, the labial palps forming sheaths which enclose three needle-like pricking organs, recalling the lancets of the gnat. The eggs of a flea are white and oval. They usually drop to the ground, and the tiny, white, worm-like larvae thrive in any little accumulation of dirt, feeding on it. They make, when full-grown, little cocoons covered with dust, inside of which they pupate, the perfect fleas emerging in a week or two, and then feeding as parasites on the blood of some animal host.

The flea which troubles man is *Pulex irritans*, but there are many other fleas peculiar to other mammals or to birds, and these will often transfer their attentions from one kind of animal host to another.

Classification of the Diptera mentioned in Chapters XXV. and XXVI.

Sub-order 1. **Brachycera.** Short-horned Flies.
  Family 1. Muscidae.
    Genera. *Musca* (House-fly).
      Calliphora (Blue-bottle).
      Glossina (Tsetse-fly).
  Family 2. Syrphidae.[1]
    Genera. *Syrphus* (Hover-fly).
      Volucella.
      Eristalis (Drone-fly).
  Family 3. Stratiomyidae.[1]
    Genus. *Stratiomys* (the Chameleon-fly).
Sub-order 2. **Nemocera.** Thread-horned Flies.
  Family 1. Culicidae. Gnats.
    Genera. *Culex* (the Common Gnat or Mosquito).
      Anopheles (the Spotted Gnat, the Malarial Mosquito).
      Corethra (the Phantom-fly).
  Family 2. Chironomidae.[2] Midges.
      Chironomus (the Harlequin-fly).
      Tanypus (the "Splay-footed" fly).
      Ceratopogon (the Horn-bearing fly).
  Family 3. Simuliidae.[2] Sand-flies or Buffalo-gnats.
      Simulium (the River Sand-fly).
  Family 4. Tipulidae. Crane-flies.
      Tipula (Daddy-long-legs or Common Crane-fly).
      Pachyura maculosa (the Spotted Crane-fly).
  Family 5. Cecidomyidae.[2] Gall-midges or Gall-gnats.
    Species. *Cecidomyia taxi* (the Yew Artichoke Gall-midge).
      Cecidomyia destructor (the Hessian-fly).
      Cecidomyia ulmariae (the Meadow-sweet Gall-midge).
Sub-order 3. **Aphaniptera** (sometimes separated as a distinct order).
  Family. Pulicidae. Fleas.
      Pulex irritans (the Common Flea).

[1] For identification of species of these families see G. H. Verrall's *British Flies*, vols. v. and viii.

[2] For detailed account of these families see Theobald's *British Flies*, vol. i.

Practical Notes on Diptera Nemocera

1. Examine the contents of any rain-water tub during the summer months; probably several different kinds of dipterous larvae can be obtained from it with the aid of a small muslin net. Sort these out, transferring some of each kind to a separate tank of clean rain-water, at the bottom of which a layer of mud and decaying leaves has been allowed to settle.

Distinguish, amongst the larvae captured, those of the Gnat, the Harlequin-fly, and *Tanypus*. Examine these, if possible, under the microscope. Look for their eggs and pupae. Sketch the different stages of each insect found, and watch their habits and development, making careful notes.

Amongst the flies that emerge, distinguish the males and females, and sketch them from the side in their characteristic attitude when at rest.

2. In any fairly clean stagnant pond, dip with a net for the various stages of *Corethra* and *Ceratopogon*; when found, study them as suggested in paragraph 1.

3. Search a swift, clear stream for the early stages of the River Sand-fly (*Simulium*), and study them. Watch for the moment of emergence of the fly from the pupa, and determine how the fly is protected from death by drowning, as it rises from the submerged pupal cocoon to the surface of the water.

4. When digging in the garden or field, or removing plantains from a lawn, search amongst the bases of the grass stems for *Tipula* larvae or pupae. Catch adult *Tipula* specimens and distinguish between the male and female. Verify all the points mentioned in the text.

CHAPTER XXVII

INSECTA (*continued*)

Order: HYMENOPTERA (ANTS, BEES, WASPS, GALL-FLIES, ETC.)

General Characteristics. THIS order is one of the largest and most highly developed of all the Insecta. In structure, all are alike in possessing four transparent, relatively small wings with few nervures. The two wings on either side are held together by minute hooks, so that, in flying, two wings function as one (Fig. 313). The mandibles are large and strong, being used not only for biting food and for carrying, but also in excavating and in shaping the cells for the young. In some Hymenoptera, a special proboscis formed from the other mouth-parts is also present which is used in obtaining food, as in the Bees.

In all of them the front, "thoracic" mass of the body is formed, not only of the three thoracic segments, but also of the first abdominal segment, which is more or less fused with these. In many the second abdominal segment forms the "petiole," or constricted waist-segment, behind which comes the "gaster" or hind body, usually spoken of as the abdomen, though the name is not strictly applicable, any more than it is strictly correct that the fore body should be termed the thorax, since it includes one abdominal segment. However, to avoid multiplication of technical terms, the whole fore body will here still be called the "thorax," the inverted commas indicating that the term is only adopted and not strictly applicable. In the adult, the number of segments in the body is variable, but in the larva there are thirteen behind the head, though the full number is not always visible externally.

The metamorphosis is great, and takes place during a resting pupal stage. The social habit is common, with a differentiation of castes of individuals in many of the Societies.

Classification. The following families of the Hymenoptera will be considered here :—

Sub-order *Aculeata* (possessing a sting).	Bees (*Apidae*). Social Wasps (*Vespidae*). Solitary Wasps (*Eumenidae*). Digging Wasps (*Pompilidae* and *Sphegidae*). Ants (*Formicidae*).
Sub-order *Parasitica* (having an ovipositor instead of a sting).	Saw-flies (*Tenthredinidae*). Wood-wasps (*Siricidae*). Gall-flies (*Cynipidae*). Ichneumon-flies (*Ichneumonidae*). False Ichneumon-flies (*Braconidae*).

Fig. 309. (The Honey Bee (*Apis mellifica*).

Family : Apidae (Bees)

Bees are large insects with hairy bodies ; these hairs are very sensitive, and must be a valuable possession for a creature covered by an insensitive, chitinous skin. Many bees live socially in colonies with a differentiation of the individuals into three castes : queens, males, and workers (incompletely developed females), all of which are winged. The food consists of pollen and nectar, the latter being obtained from flowers by means of the lengthened, modified mouth-parts which form the proboscis characteristic of the family.

The Honey Bee (*Apis mellifica*).[1]

Constitution of the Colony. Honey bees live a social life in communities of many thousands. During the greater part of the

[1] Much of our knowledge of Bee life we owe to the ingenious experiments devised by Francis Huber of Geneva, the blind naturalist. In spite of his great affliction, he was able—owing to the help of his devoted servant, Francis Burnens, who literally became eyes to him—to devote himself for many years to the study of Bees, publishing in 1789 the results of his researches in a book entitled *Nouvelles Observations sur les Abeilles.*

year only two kinds of adult individuals can be found in the hive, the thousands of "workers" and the one "queen," though through the summer months several hundred males or drones are also present.

The Queen.

The queen (Fig. 309) is considerably larger than the workers, with a longer abdomen, but with relatively shorter wings. She is the sole mother of the hive, and remains constantly within it, tended and fed by her workers, and laying eggs in the cells prepared by them. She, like them, has a sting, but will use it only against another queen.

Worker Bees.

Each worker bee has the structure shown in Fig. 309. The head, "thorax," and gaster ("abdomen") are distinct, the gaster being separated from the "thorax" by a narrow, short petiole, or waist, which is obscured by the hairy front margin of the gaster.

Head.

The head bears two large compound eyes, each with over 6000 facets in it (for structure see Figs. 158 and 159); also there are three simple eyes on the centre of the forehead; the latter are probably used for examining objects close by, whilst the compound eyes have wide, long vision.

In front of the head project the bent antennae, each very freely movable, with a long joint next the head, and an eleven-jointed tip projecting at an angle to this (Fig. 310).

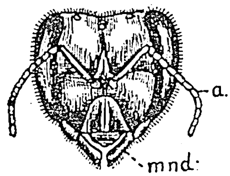


FIG. 310.—Head of Honey Bee seen from in front, with proboscis hidden. *a*, Antenna; *mnd*, mandible.

These antennae seem undoubtedly to be the organs of communication between bee and bee. Bees, when they meet, constantly cross antennae, and stroke each other with them, or sometimes with a swift, agitated movement tap a comrade, apparently to attract attention.

The antennae, besides being covered with sensitive, tactile hairs, have their surface dotted with thousands of little hollows, each with its own nerve supply, and it is thought that these structures are organs of smell. It is undoubted that bees have a marvellous power of detecting the presence of honey — they are said to be guided by the scent of flowers a mile or more away.

Other smaller hollows on the antennae may have an auditory function.

On each side of the mouth is placed one of the hard jaws or mandibles, of which much use is made when forming the waxen cells of the comb (see p. 410). The characteristic proboscis will only be seen when it is actively in use in obtaining food, or when the head of the Bee is viewed from the side; for when at rest, it is bent back and lies in a groove on the under side of the head (Fig. 312, *t*). The upper lip (labrum) is small, and the mandibles are quite apart from the proboscis, which is formed from the lower lip (labium) and the soft jaws (maxillae). The parts of the proboscis are shown artificially spread out in Fig. 311; the maxillae form together the outer, horny sheath, and the labium its central portion, which consists of the long hairy tongue or ligula and a trough-like lower sheath formed by the labial palps, within which the ligula lies. The free tip of the tongue is a little spoon-like structure; with this the nectar of flowers is lapped up; the hairs of the tongue get soaked in the fluid, which is then sucked up by the surrounding tube and passed into the mouth, after having been thinned by the addition of some of the secretion of the salivary glands of the bee, which causes the transformation of the *nectar* of the flowers to *honey*. The former consists of 70 per cent of water and nearly 30 per cent of *cane* sugar, whilst the latter has only about 7 to 10 per cent of water, the rest being *grape* sugar; *i.e.* honey is nectar which has been

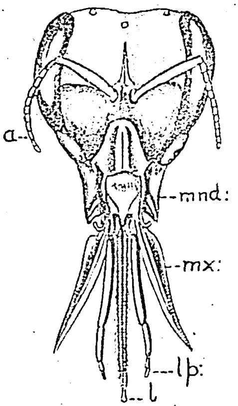


Fig. 311.—The Head of the Honey Bee seen from in front, with the Proboscis extended and its parts spread out.

a, Antenna; *mnd*, mandible; *mx*, maxilla; *lp*, labial palp; *l*, ligula.

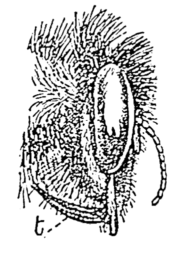


Fig. 312.—Head of Honey Bee seen from the side, with the Proboscis, *t*, turned back below the head.

digested by the bee, and regurgitated for storage in this condition.

The mouth-parts are therefore modified in the bee for two quite separate functions, the mandibles chiefly for constructive work in forming the honey-comb, the maxillae and labium for obtaining food.

The Thorax. The thorax, which lies behind the head, consists of the usual three segments, together with an abdominal segment fused with them as explained on p. 401. Each thoracic segment bears, below, a pair of jointed legs, and the second and third segments bear also, attached to their upper surface, a pair of delicate, transparent wings.

The wings are held together so closely that at first sight there appears to be only one on each side. If they are separated from the body of a dead bee, and examined under the microscope, the method by which this union is maintained can be seen. The front margin of each back wing bears a row of little hooks (Fig. 313), which catch in a groove on the hind margin of the front wings, so that when flying the two act as one. When at rest the front wings slip over the back wings, thus releasing the lock, and both then lie horizontally over the back, but when they are again spread for flight, once more the two margins are automatically hooked together.

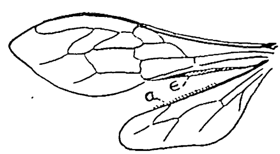


FIG. 313.—Wings from the right side of a Honey Bee, seen from below.

e, Upturned edge of the front wing; *a*, hooks on the back wing.

The legs are worth detailed study, for each pair has some special adaptation fitting it to perform some special function, besides the general function of locomotion, in which they all share alike. Each leg ends in two long and two short movable claws with a little pad between them. The claws enable the bee to climb rough surfaces, and to hang, when necessary, clinging by them (see p. 409); while the pad, which can secrete a sticky substance, enables it to climb up smooth, slippery surfaces as a fly does (p. 369). The joints of the legs are similar to those found in all insects, but each leg has on it a characteristic special structure. On the first leg, at the joint between the fourth and fifth segments, there is a special little arrangement for cleaning the antennae

and perhaps also the proboscis and the hairs that are present between the facets of the compound eye; this is known as the "comb," and consists of a small depression lined with hairs on the fifth segment, and a little prong which projects over this from the fourth segment. On each middle leg there projects from the fourth segment a longer, stouter prong, which is used in digging the pollen out of the "pollen-basket" (see p. 413), and also for preening the wings. The back legs are the most complex (see Fig. 314, *C*). On each there is, on the outer, upper side of the fourth joint, a deep depression fringed round with stiff hairs; this is known as the "pollen-basket," for in it the pollen obtained from flowers is carried home to the hive. The pollen is first collected on the hairs which cover the body, and then brushed into the baskets by the hairy legs, and especially by the enlarged joint below each "basket"; this joint is beset with rows of stiff hairs, which brush the pollen off the body into the basket of the opposite side.

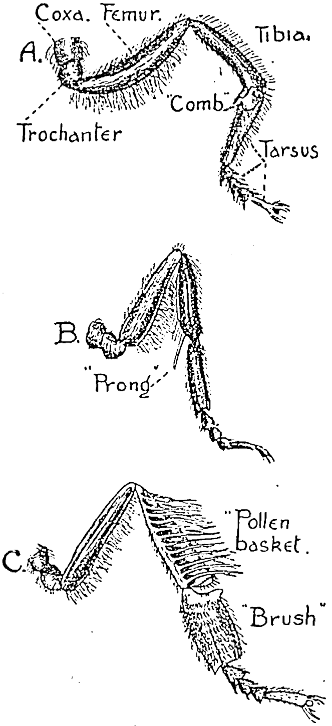


FIG. 314.—The Legs of a Honey Bee. *A*, front leg; *B*, middle leg; *C*, back leg.

The "Abdomen" or Gaster, and the Sting. The gaster is segmented, five segments being usually distinguishable. Situated at its free tip is the sting, a complicated and perfect piece of mechanism, by which the skin of the victim is pierced, and poison injected into the wound (Fig. 315). The central part of the sting consists of three special structures, a pair of slender, pointed lancets, or "darts," barbed at the tip, and a central, deeply grooved piece, called the director or guide, also finely pointed and barbed at the end. The darts lie

in the concavity of the guide, being fixed to it by a sliding junction consisting of two beadings running along within the guide-groove, one on each side, each of these fitting into a groove in one of the darts. The darts can be slid along, so that their tips project beyond the end of the guide. These three dark-coloured, piercing organs are enclosed between a pair of fleshy structures, the "sting-palps." Connected with the base of the sting is a two-branched, tubular poison-gland and a poison-sac about the size of a small pin's-head; when

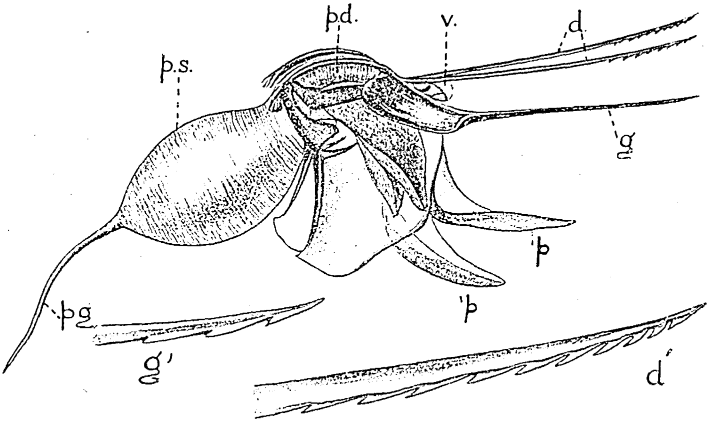


FIG. 315.—The Sting of a Bee removed from the body and spread out.
d, Darts or lancets; *d'*, tip of dart, further enlarged; *g*, guide or director; *g'*, tip of guide enlarged; *p*, palps; *pg*, beginning of poison-gland; *ps*, poison-sac; *pd*, poison-duct; *v*, valve.

the sting is being used, this poison is forced down a tubular cavity between the "darts" and the "guide," and entering the wound made by them may cause pain, though the susceptibility of people to the poison varies a good deal—also, after a certain number of stings have been endured, the poison usually ceases to have any ill effects.

Sometimes, when a bee stings, it presses the lancets only a little way into the flesh, and if left undisturbed it can then withdraw them, but if they are pressed right in as far as they will go and then an attempt is made by the bee hastily to withdraw them, the whole sting usually becomes separated from its body; in this case, the insect dies soon afterwards, and

also the effects of the sting on the victim are more severe. The possession of a sting is confined to the queen and worker bees.

In all cases of stinging Hymenoptera (*Aculeata*), the sting seems to be developed from the same structures as the ovipositor, which is conspicuous in the non-aculeate forms.

The worker bee seems to be an imperfectly developed female; occasionally she will lay eggs, and these, though never fertilised by a drone, will develop into new drone bees; such parthenogenetic eggs are fairly common amongst the Hymenoptera.

Males or Drones.

The males or drones are larger and broader in build than worker or queen, and have bigger wings, but their brains are smaller. Their eyes, which meet across the top of the head, are also relatively larger and have many more facets — over 13,000 altogether, according to Langstroth;[1] perhaps they need a wider range of vision in their pursuit of the queen at mating time. They do none of the ordinary work of the hive, neither collecting food nor caring for the young, and they are therefore without some of the special structures possessed by the worker, having no "pollen-baskets," no sting, and only a short, weak proboscis. The queen also lacks pollen-baskets and the long proboscis.

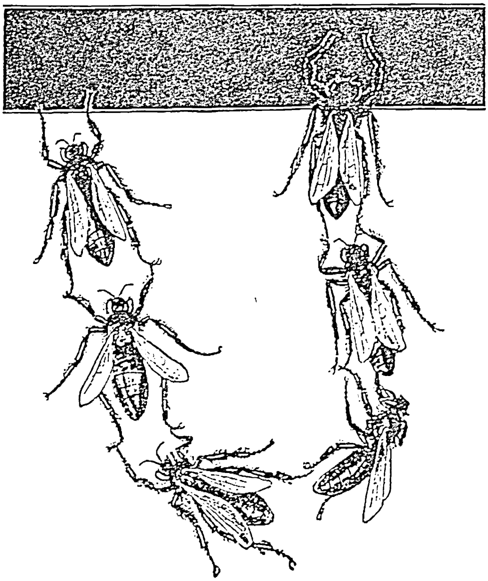


FIG. 316.—A festoon of Worker Bees, showing how they cling together.

[1] Langstroth, *The Honey Bee*, published by Dadant & Sons.

The Life in the Hive. The life in the hive can perhaps best be followed in the history of a swarm which, during the summer, has left the old hive or nest to start a new colony. This swarm, if the first of the season, will consist of the old queen and some thousands of workers. On leaving the hive on some still, sunny morning, the swarm will fly straight to a convenient tree, or other object, where the queen alights, all the workers clustering round her in a dense mass, the lower bees clinging on by their front legs to the back legs of those above them (Fig. 316). Thus they remain motionless for a time, and it is now that the bee-keeper hastens to catch the swarm in an inverted straw "skep," and to convey it to the hive in which it is desired that it shall permanently live; otherwise, certain of the bees leave the swarm and go out to find a suitable hollow tree or other cavity where a nest could be made. They come back and apparently communicate their find, for suddenly the whole swarm, with its queen, will detach itself, and fly off to take up its abode in the spot chosen. At the time of swarming, so absorbed are the bees in the ecstasy of the moment, that they may be freely handled without fear of a sting.

Forming the New Home. When the new home has been taken possession of, at once some of the workers begin to fill up any cracks in the walls, using for this purpose the glue-like substance called "propolis," which they collect from the sticky buds of such trees as the poplar, carrying it home in the pollen-basket after it has been worked up into a little ball. They leave usually one opening as the entrance to the hive. Then these workers join others who have already commenced the formation of the cells in which the honey is to be stored, and in which the new young bees are to be reared.

Wax Secretion. The wax of which these cells are to be formed is secreted chiefly by the younger workers, and appears in the form of little scales which gradually protrude from below the segments on the under side of the abdomen; four pairs of these wax scales are formed (Fig. 317). This secretion of wax, however, is only possible when the insects have been well fed, and we find that before swarming they generally feed freely from the honey and pollen stored in the hive, and that as soon as they have secreted one set of wax

plates, they go off to the flowers and feed again. The first bee in the new hive that is about to secrete wax, climbs to the roof of the hive, and suspends herself there by her front legs, whilst the second clings to the back legs of the first, and the third to the second. Others form similar festoons until a dense curtain of bees is hanging from the roof, their close association causing a considerable rise of temperature in the mass.

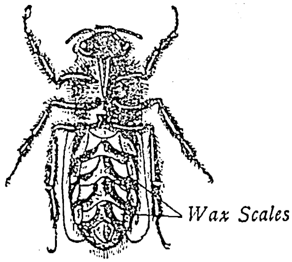


FIG. 317.—The under side of a Worker Bee carrying wax scales. (×2.)

They hang thus, quite motionless and silent, for twenty-four to forty-eight hours, and then the scales of wax appear.

Each bee, as her secretion is completed, detaches herself from the cluster, and climbs to the highest point of the hive, and there fixing herself with her front claws, she nips off the wax scales one after the other, using for this purpose the broad margins between the two largest joints of the back legs (Fig. 314), which form efficient nippers. Then she works the wax up into a soft thread with her mandibles, moistening it with her saliva, and finally attaches the thread to the roof of the hive and goes off to feed once more. Bee after bee repeats the same performance until a shapeless mass of wax hangs from the roof.

Cell Formation. Older bees now come and begin to hollow out in this mass beautifully-shaped, hexagonal tubes, side by side, which finally form two vertical layers of tubular cells lying back to back, the base of one cell forming usually one-third of the base of each of three cells in the opposite half of the whole "comb," the open mouths of the horizontal cells pointing outwards in each layer.

A large number of bees are at work at the same time on the comb, perhaps fifty on one side and fifty on the other, whilst more wax is still being added below by the younger bees. The cells are at first roughly blocked out with thick walls, the final shape being given by a further set of workers, who pare down the walls, trim them, and shape them, until the minimum of wax has been put to the maximum

of use, and the wonderful structure of the comb is the result. It is said that as many as 4000 cells may be completed in one hive in twenty-four hours—truly there is good foundation for the expression "as busy as a bee." The first cells are all alike, and in the old-fashioned straw hives or skeps, or in a natural nest, several combs hang down in parallel plates from the roof almost to the floor of the hive, though in the hives now in favour with most bee-keepers, the bees are supplied with neat square wooden frames, with an artificial, hexagonally marked wax base in each, so that they can at once start cell-making, and their energy is not wasted in wax-making when they might be storing honey or rearing young.

The First Eggs. The first cells formed are all meant for nurseries for the bee larvae, and when these cells are finished the queen approaches them; she enters a cell, head foremost, and, after examining it, backs out, inserts into it her abdomen and deposits a single little bluish-white egg, fixing it to the bottom of the cell with a sticky secretion. Whilst she is egg-laying a circle of workers surround her, ready to feed and stroke her.

In this way she enters cell after cell, leaving in each an egg, which is immediately taken charge of by one or two workers. She works hard, laying as many as 3500 eggs a day or more in the height of the breeding season! These first eggs are all alike and develop in the same way.

Worker Larvae. Kept warm by the bodies of the workers who cluster over the combs, each egg hatches in about three days, as a little, white, legless grub or larva, which lies curled up at the bottom of the cell (Fig. 318, *A*). It has a head and thirteen body-segments. The "nurse-bees," who are usually some of the younger workers, now feed it, for they alone can manufacture the pap on which the grubs are at first fed; they secrete this pap from a special salivary gland opening into their mouths. Soon, however, the grub is put on a diet of pollen and honey made into a soft paste, which is brought in from outside by the older workers, and placed in the cell so that the larva lies partly immersed in it, and can feed as much as it will. In about five days, during which time it has changed its skin several times, the grub is full grown, and nearly fills the cell, in which it now lies longitudinally, with its head towards the open end. At

this stage the nurses form a convex cap over the mouth of the cell. This cap is formed of a porous mass of pollen and wax, which allows air to pass through, instead of the almost impervious pure wax used in closing up the honey cell. The imprisoned larva begins to spin, from a gland on the lower lip, a silk thread with which it makes a little mass of interwoven threads at the mouth end of the cell. These threads partly cover the body, forming an imperfect cocoon.

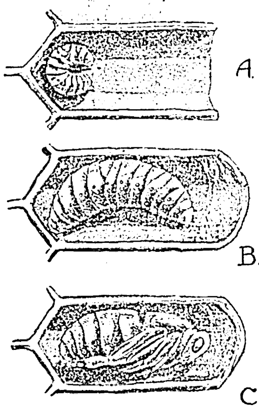


FIG. 318.—Three separate Cells from the Brood-comb of a Honey Bee, showing a young larva *A*, a full-grown larva *B*, and a pupa *C*. (×2.)

The Pupa. In about two days the larva pupates, appearing finally as a pupa in which the organs of the adult bee are clearly visible through the transparent skin in which it is swathed. This stage lasts for seven or eight days; then the pupal skin is cast off and the young bee is ready to emerge. With its jaws it breaks the silken threads of the cocoon and bites round the cap of the cell—sometimes helped by a nurse-bee—until the cap swings back on a little hinge-piece, and so is readily pushed aside. As the young, grey, downy bee comes out, she is met by workers who clean and brush her, and feed her with honey, so that after a few hours she is able to take her share in the work of the hive, her first duty being to act as a nurse to the grubs.

Storage of Food. Soon enough new workers have been added to the population for the older workers to be free to go out and collect the nectar of the flowers, and this they do most industriously, sucking up the nectar with the proboscis and then swallowing it, passing it into a temporary store-chamber of the alimentary canal called the "honey-sac," situated in the front part of the gaster, whence it can be readily regurgitated in a slightly altered state, forming honey. Incidentally, they collect much pollen on the hairs of their bodies as they crawl over the flowers, and this they brush into the pollen-baskets, having first

moistened it slightly so that it will stick. Having got their full load of honey and pollen they fly back to the hive, and, regurgitating the honey, they may feed with it the queen or any hungry workers they meet, or they may at once store it in cells in a special part of the comb. Next, they dig the pollen out of their baskets with the prong on the middle leg adapted for this purpose (Fig. 314) and press it with their back legs into other storage cells nearer the brood-combs, where, by other workers, it is further kneaded up with a little honey, forming "bee-bread." The honey is kept safely within the comb, partly by the slight upward tilt of the cells on each side, and partly by its own stickiness, which causes it to adhere to the little roughnesses in the wall of the cell. When a cell of honey is full, and not required for immediate use, it is left for some days to thicken slightly, and then, to keep it from fermenting, a drop of acid is let fall on to it from the sting of a worker, the cell being finally closed with a cap of wax. It is said that the honey, and also the pollen, from different kinds of flowers is always stored in separate cells. One bee may make as many as thirty visits an hour to the flowers. Young bees usually make their first flight from the hive when about eight days old; they fly close round about in a hesitating manner, as if learning to use their wings and to find their way about; they have to learn to recognise their own special home. Their second flight, about a week later, is a business trip, when they fetch back their first load of honey.

In early spring, when pollen is scarce, bees will gather flour or meal in its place, if they can find it; many bee-keepers feed them with this at the beginning of the season.

Other Work of the Hive. Whilst some workers are acting as an escort to the queen, and others are busy looking after the larvae or collecting food, there is much other work also to be done. Many are still occupied in building more and more cells to keep pace with the ceaseless activity of the queen-mother, and the industrious storing of food by the workers; others are busy ventilating the hive by the continual vibration of their wings; others in keeping the whole hive scrupulously clean, carrying outside any dirt that may accumulate, any intruder that may have ventured in, or any fellow-bee that has died within the hive; others

2 E

again seem to act as sentinels at the door, chasing away alien bees or other intruders. At our first glance at a hive, confusion may seem to reign, for so many are coming and going; but as we watch, the order behind the apparent confusion becomes gradually evident. So all goes on methodically and busily during the summer months, the workers often wearing themselves out with their strenuous activities in six or seven weeks, though the queen, who is so well fed by them, and so assiduously cared for, may live four or five years.

The Approach of Winter. As cold weather approaches and honey becomes difficult to get, the bees quit the hive less and less often, the grubs, which are still developing, being fed on pollen from the stores. The whole activity of the hive lessens, the queen ceases to lay eggs, and the bees all cluster round her on the top of the honey cells, and there remain crowded together and beating their wings for warmth. They feed now on the honey in the cells, which is licked up by those nearest it and passed on from one to another until all are fed. They remain in this more or less torpid condition all the winter, the only visible movement occurring when those on the outskirts of the mass, getting chilled, make their way inwards to the warm centre, a continual circulation of the bees being thus kept up.

The Spring. The following spring, the increasing warmth of the sun begins gradually to arouse them once more to active life. Even a warm day in January will entice out a few bees, and all the early spring flowers are eagerly visited by them; it is as if, after their long imprisonment in the dark hive, and their dependence on "preserved" honey, they crave once more the taste of the fresh nectar, to be obtained, after an invigorating fly through the air, direct from the heart of a flower, with the sunshine bathing everything in warmth and light—a change indeed to be eagerly welcomed.

Preparations for Swarming. By April all is once more in full swing; the queen has been laying eggs since February, soon the hive will become overcrowded, and to relieve this, one or two new swarms must go off to found new colonies. Now the workers begin to prepare for this exodus. The most necessary provision is the rearing of the males or drones, and the rearing of a new queen or mother-bee to take the place of the one who goes off with the first swarm.

Drones. The cell-makers begin, therefore, to construct rather larger cells (Fig. 319, *D*), and the queen, though apparently reluctant to enter these, will do so when she finds no smaller ones, and in each she lays an egg which appears quite similar to those laid before, but which will develop into a drone or male bee. What the actual difference is between the drone-egg and the worker-egg we do

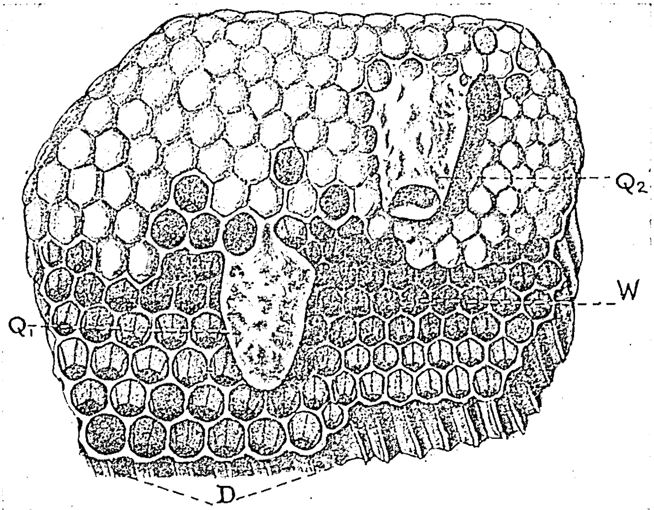


Fig. 319.—A Piece of the Brood-comb of a Honey Bee.
W, Cells in which worker bees are reared; *D*, cells for drone bees; Q_1 and Q_2, cells for queen bees.

not yet know for certain, but it seems now to be proved that the drone-eggs are unfertilised and develop parthenogenetically, for the virgin queen, before she goes for her marriage flight, often lays eggs which invariably develop into drones. It has been suggested[1] that the greater width of the drone cells and the consequent position of the queen's legs in ovipositing may check the discharge of the sperm cells from the sac in which they are stored after copulation, and that consequently the eggs pass out unfertilised; but this view is disputed by Langstroth.[2] Some four or five hundred drones

[1] F. Cheshire, *Bees and Beekeeping*.
[2] Langstroth, *The Honey Bee*.

arise in a colony of thirty to forty thousand workers, but in a larger colony their number is greater. These drones do no work in the hive, but are fed on honey by the workers, or help themselves from the honey-comb. They sleep a large part of the day in corners of the hive, going out on warm sunny days between twelve and three o'clock for a short fly and a sleep out-of-doors, tucked away in the corolla of some flower. The only time when they really arouse themselves is when they join in the giddy upward rush of the marriage flight with the new young queen.

The New Queens. After enough drone brood-cells have been provided we find special "royal cradle" cells appearing. It seems that usually[1] the egg that is to produce the new queen is just like the ordinary "worker" egg and is laid in an ordinary cell at the edge of a piece of brood-comb, but that the workers determine its fate, first by feeding the larva on "royal jelly," a richer, sweeter, more nutritious food than that on which the worker larvae are fed after the first day or two, and secondly by enlarging the cell and altering its shape so that finally it is somewhat the size and shape of an acorn, placed vertically, and opening below by a rather narrow aperture. Five or six of these royal cells may be formed, the eggs in them differing in age by a day or two, so that the young princesses will hatch out in succession. The larva hatches in three days, and is full-grown in five more days, when it is sealed up in its cell and pupates. In seven more days it is fully developed, and the young queen begins to attempt to get free from her cell.

That it *is* the food and special cell which cause the development of the egg into a queen, or fully developed mother-bee, seems to be shown[2] by the fact that if anything happens to the egg in the queen cell, the workers can bring up a worker larva in such a way that it becomes a queen. They choose a larva not more than three days old, and enlarge its cell by biting away the cells all around and building up a queen cell round it. They then feed it on the royal jelly exclusively, and it becomes a queen-bee.

The new young queen is not allowed to emerge until

[1] Langstroth, *op. cit.*

[2] This view may, however, have to be reconsidered in the light of Von Ihering's observations on the stingless bee of S. America (quoted in W. M. Wheeler's *Ants*, p. 105).

the old queen has left the hive with the first swarm of workers, for, if the two queens met, they would fight until one stung the other to death. It is against another queen alone that a queen will use her sting, and no queen will brook a rival in her hive.

Swarming. At this time the greatest excitement prevails in the hive, which is now so overcrowded that hundreds of bees can find no entrance and remain in heaps outside. Twenty-four hours before she actually departs, the queen, irritated apparently by the humming noise that the young queens still imprisoned in their cells are beginning to make, rushes wildly about and tries to get at the royal cells to kill her rivals, but is driven off by the workers. She then wanders off, aimlessly visiting every corner of the hive, no longer with a respectful escort of workers, but pushing through them in any direction, sometimes even carrying on her back some of her former attendants.

A large part of the community ceases to take any part in the ordinary work of the hive. The workers about to emigrate feed unchecked from the honey cells, and so prepare for their coming flight, and all keep up a very frequent and peculiar humming and vibration of the wings.

Finally, when the sun is bright and high in the sky, the queen will rush from the hive, followed by thousands of her workers, and with a loud humming the whole swarm flies to the nearest tree and settles there. This is the point from which we began the story of the hive on page 409.

The first swarm, which goes off usually in May or June, will always be led by the old queen, unless she is so old and decrepit as to be useless, when she either stays in the hive until she dies naturally, or is put to death by the workers, who may press round her until she is suffocated, but who never use their stings against her. In such a case, the first swarm will be led by a new young queen, who has not yet been for her marriage flight, and this is always so in all subsequent swarms.

The Second Swarm. As soon as the first queen has left the hive, the oldest "princess" is allowed to emerge, the workers helping her to bite away the end of her cell, and tending her carefully, for she is weak and pale just at first. In a very few minutes, however, she gets stronger,

and seems to become sensible of the presence of other young queens in the royal cells around, and to have an instinctive jealousy of them, for, if not stopped, she will now throw herself upon one such cell, and, tearing it open, sting the inmate to death, passing on to each in turn, until she herself is left queen without rival. If, however, the colony is a very numerous one, the workers will not allow her to touch the royal cells, in which case she protests with a shrill, angry cry, rapidly repeated, which seems to evoke an answering but deeper note from the imprisoned princesses; however, she soon accepts the inevitable and leaves the hive and goes off with a second swarm of workers and drones to form a second new colony; even a third swarm sometimes can be spared.

Occasionally, though not often, two young queens emerge at the same time, and they then fight for supremacy, whilst the workers surround the two combatants in a ring. They seize each other with their jaws and feet, and hold on until one manages to insert her sting in a soft part of her opponent's body, causing immediate death. The sting is then carefully withdrawn so that the victor is uninjured. When the last swarm has been given off, the next queen that emerges is always allowed to kill any others that may still be waiting in the royal cells.

The Marriage Flight. The new young queens, before they can start on their special work for the hive, must go for the marriage flight with the drones, and this strange event must next be described. Within a few days of the founding of the new colony, or the birth of the last new queen in the old colony, the young queen, one sunny, still morning, often at about midday, will come to the door of the hive, and hesitatingly issue forth, go in and out once or twice, and then after a little hovering around, as if to fix in her mind the position of her home, which she has never before seen from without, she suddenly soars off all alone, rising ever higher and higher towards the sky. Now she is seen by the drones, who are out from all the hives around, and they dart after her. Maeterlinck, in his *Life of the Bee*, describes, in words which none can equal, how they pursue her, but one after the other falls back exhausted in the chase, till finally, far up in the clear air, in the region unhaunted by birds, who might attack them, the strongest, swiftest of the drones, who

alone may win the queen, reaches her side, and together they whirl still higher in a brief moment of union—then it is all over, the drone falls back to earth dead, having given his life for this one ecstatic moment, and the queen returns to her home, where she is welcomed by her waiting subjects, to leave it again perhaps twice only in her life, when she may lead forth new swarms. Now for three years at least, she is capable, all through the summer months, of laying fertilised eggs at a rate of many hundreds, sometimes thousands, a day. She alone is now responsible for the whole future population of the hive.

The Massacre of the Drones.

All goes on regularly and methodically in the hive until the approach of winter; then the workers seem to realise all at once the danger of still having to support in the hive many hundreds of useless drones who have never found a mate, and who still lurk about in corners doing nothing and using up the stores of honey. Suddenly, therefore, one day in autumn, the workers set upon them and sting or bite them to death, and throw out their dead bodies—not a single drone is left alive; the bees are preparing for the hardest time of their lives, the long winter, when they have to stay within the hive and live on the honey they have stored; the one drone who flew aloft with the queen accomplished the work for which all the drones were fitted, and the now useless remainder cannot be tolerated in the hive any longer.

The Spirit of the Hive.

It is a strange history, the history of the hive. Nowhere else in the animate world do we see the life of the individual so absolutely subject to the life of the community, and yet at the same time dependent on it—for an isolated bee, under whatever favourable conditions of warmth and nutrition, will soon die, apparently from loneliness. Think what is sacrificed for the hive, by the workers especially! Their own life is limited on every side, even their physical development is checked (p. 408), their whole time and energy is given to the building of the fabric of the hive, caring for the young, laying up stores of food for the community, and other necessary duties; so hard do they work, indeed, that their lives often endure only a few short weeks, though in the case of the foragers, at any rate, this life is a merry one, lived largely in the sunshine, flitting from flower to flower. An old bee can be recognised by its ragged wings

and shiny, hairless body. The queen certainly is fully developed, but her life, except for the great events of her marriage flight and her departure, perhaps in two successive years, with a swarm to a new home, is confined within the dim-lit hive, and is almost entirely limited to reproductive activities. The drones alone seem to stand aside, and to fail in obedience to the law of the spirit of the hive, which enacts that each shall work for the good of the whole. Truly they essay to perform their special function on that wonderful flight which they make with the queen, but failing that, they are nothing but a drag and a burden on the community, and hence it may seem merely instinctive, stern justice that is meted out to them at the end of the summer.

With all this power of working together and this devotion to the common good, the individual bees seem, nevertheless, to care little for each other in the way in which we understand the term. A sick bee is ignored or callously pushed aside by any passing neighbour, and they seem to have no idea of helping one another in difficulties, though their devotion to the queen is entire. Her they defend with their own bodies, and feed with the last drop of honey in the hive, so long as on her the whole future of the community depends. The loss of their queen greatly disturbs them, and they will not at once accept a new queen if one is introduced to them. In fact, they will often attack and kill her. Bee-keepers, therefore, when it is necessary, introduce a new queen protected by a little wire cage so that the bees gradually get used to her presence. In time they will begin to feed her, and then it is safe to remove the cage, and she will be accepted by them as queen.

Powers of Communication. That bees can communicate with each other seems indubitable. Their antennae, which they constantly cross with the antennae of any fellow-bee they meet, are covered with short, sensitive hairs, and with thousands of minute structures, which are looked upon as being probably organs of hearing and smell, though their function has not yet been determined with certainty. Maeterlinck and others have shown that if a bee is enticed to feed on a special supply of honey some little distance from the hive, she will quickly return with other bees, to whom it appears she must have communicated her find. It seems, however, that

more experiments are necessary to establish the degree of power of communication. The humming of bees, which varies in tone and intensity according to the occasion which calls it forth, is produced in two ways: a deeper note, such as heralds the departure of a swarm, is caused by a certain rate of vibration of the wings; whilst a shriller note, such as that of an angry bee, is caused by the vibration of the integument over the thorax, moved by the muscles within which are attached to it. A usual rate of wing vibration at normal times is 440 times a second; in a tired bee the rate drops to 330 times a second, and the pitch of the note produced drops correspondingly.[1] The hum of a drone is more sonorous than that of a worker. There is a whole gamut of sounds, the exact significance of which we do not know—indeed we are not even sure that these sounds are audible to the bees themselves; possibly their power of communication by the touch of antennae suffices, without any need for communication at a distance by sound, though on the other hand it is said that the hum of the young queen bee trying to get free from her cell is noticed by the old queen who is about to leave the hive, and has a curiously agitating effect on her.

Other Social Bees.

Humble Bees.

During the summer Humble or Bumble Bees are to be found living together in small colonies of from 200 to 300 individuals, but at the end of the season all die except the young queens, who alone can survive the cold of winter, hibernating in some crevice, or under the moss on a bank, or in a small burrow excavated in the earth; consequently, each spring, new colonies have to be started by the solitary young queens.

Bombus terrestris.

The large Earth Humble Bee (*Bombus terrestris*), the commonest species in England, makes her nest underground, often using the deserted burrow of some small animal such as the field-mouse.[2] She weaves the little pieces of grass, which the mouse has collected, into a ball with an opening at one side just large enough to allow

[1] A. S. Packard, *A Text-Book of Entomology*, 1898.

[2] For most of the following details I am indebted to Mr. F. W. L. Sladen's delightful book, *The Humble Bee* (Macmillan, 1912).

her to creep through into the central cavity where she will lay her eggs; then she collects from the earliest spring flowers[1] some pollen and honey, and deposits a little mass of honey-pollen-paste on the floor of the cavity of the nest; next she builds up on this paste floor a little circular wall of brown wax, within which she lays a batch of eggs, immediately afterwards closing up the waxen cell above them. In order that the eggs may develop they must be kept warm, and the queen broods over them day and night, only leaving them occasionally to get the food necessary for herself, and soon also for the developing grubs; she stores some of the honey collected during the day in a special, egg-shaped, waxen cell which she constructs just in the entrance of the brood-cavity of the grassy nest, and from this store she sips during the night. After four days the eggs hatch as little legless grubs, which still remain hidden within the waxen cell, feeding on the pollen-paste which forms its floor; as this is used up the queen

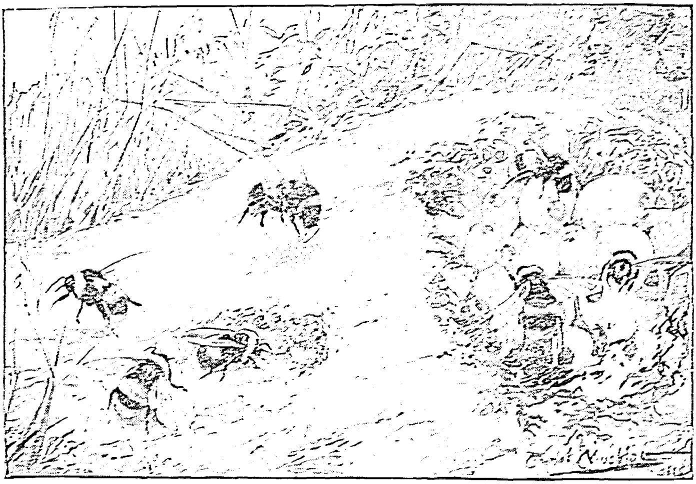


FIG. 320.—The Nest of a Common Humble Bee. (After Muckley.)
(Part of the covering of the nest is removed to show the cocoons.)

[1] The red clover is dependent upon the visits of Bumble Bees for the fertilisation of its seed. When red clover was introduced into Australia it was found necessary also to import Bumble Bees in order to get ripe seeds.

replenishes it, and she also passes in to the grubs a liquid mixture of pollen and honey, through a little hole which she makes in the thin wall of the cell. As the larvae grow they are apt to break the waxen wall which confines them, and so it is constantly added to from without by the mother-bee; in this way the size of the cell keeps pace with the growth of the larvae, until it may be as large as a walnut. Seven days after hatching, each larva spins a yellow, egg-shaped cocoon of a tough papery substance, and the queen then removes the enveloping wax, disclosing the cocoons standing upright side by side; over them she still broods, for they still need warmth.[1] Eleven or twelve days after pupation the first perfect worker bees emerge through small round holes which they bite in the upper end of their cocoons; two or three days later, these young bees are able to go out and collect food, and from now onwards they relieve the queen of much of her work; they build new cells, nurse the grubs which hatch out from the later batches of eggs laid by the queen, and also they store a limited amount of honey, often economically using for honey-pots their own discarded cocoons; these they line with wax, increasing the depth and narrowing the mouth by a fresh rim of wax but never quite closing them, for the honey is only for the immediate use of the young as they are reared, and not for winter storage; some few special wax honey-cells and pollen-cells are, however, also constructed.

In flourishing colonies a thin ceiling of wax is plastered over the upper surface of the nest cavity.

By the end of the season there are nearly 200 workers in the nest, and also many drones and new queen-bees; the drones leave the nest as soon as they can fly, and for three or four weeks they support themselves outside, feeding on pollen and honey whilst they wait for the time when the new young queens will join them in the marriage flight.

These new queens alone survive the winter, the foundress of the old colony, as well as all the workers and drones, dying at the approach of cold weather. The queen Earth Humble Bee is as much as $\frac{7}{10}$ of an inch long and $\frac{4}{10}$ of an inch broad

[1] That this, however, is not always essential was shown by some brood-comb which I brought home from a nest I excavated; for, from it, after a few days, strong, full-grown bees emerged, although, thinking the comb was merely honey-comb, I had left it exposed on my writing-table.

across the abdomen. She is black, with a band of yellow across the front of the thorax, another across the front of the abdomen, and a yellowish patch at the end of the body. The males and workers are similarly marked, but are smaller, the male being about $\frac{1}{2}$ an inch long and the worker $\frac{2}{5}$ of an inch; also in them the patch at the end of the body is almost white. Both queen and worker Humble Bees have an unbarbed, curved sting which does not remain in the wound, and therefore is much less troublesome than the sting of a Honey Bee. The queen also possesses "pollen-baskets," for she has all the food-collecting to do at the beginning of the season. The nests of Humble Bees are said to be often destroyed by field-mice and weasels.

Bombus lapidarius, the Stone Humble Bee, is also very abundant; it is as large as *B. terrestris*, from which, however, it can be readily distinguished by the bright reddish patch at the end of the otherwise black body of the queen and workers; the males have a similar red tail, but also a yellow band just behind the head. The specific name of this bee refers to its habit of burrowing its nest under a large stone.

The Moss-carding Bee.

The Moss-carding Bee (*Bombus agrorum*) is another very common, but rather smaller species. The thorax and tail are covered with tawny-brown hairs, but the rest of the abdomen is darker in colour. These bees usually make their nests in a shallow hollow in the ground or on sheltered banks. The nest is hidden by a low mound of finely divided moss and shreds of other plants, so that it is difficult to detect. The bee drags the moss along the ground until she is near her nest, moving backwards; then she tears it up with her jaws, pushing the threads under her body, and kicking them over the nest with her back legs; under the moss-lid thus made an irregular cluster of cells is constructed, and a colony gradually grows.

Unsocial Instincts in Bombus.

Amongst the small colonies of these Humble Bees are found certain very unsocial instincts, which in the more civilised Honey Bees have been eliminated by the "spirit of the hive." The Humble Bees will occasionally seize and devour the eggs in the cells—a crime never enacted in an ordinary hive. This is specially so in the fairly frequent case of a colony in which there are, besides the queen-mother of the nest, several workers that also lay eggs.

Short-tongued Solitary Bees.

The Burrowing Bee. The life of the Hive Bee is more complex and more highly organised than that of any other bee; one of the simplest, on the other hand, is that of the wild Burrowing or Mining Bee (*Andrena fulva*), often seen in spring, on garden lawns or any sandy bank, busy burrowing little tunnels in the earth. This bee lives a solitary life, and does no more for its offspring than supply it with a cell in the earth for shelter, and a little store of food on which it can feed itself. There is no social life, and no specialised workers to care for the young.

The mother-bees are a little smaller than a worker hive-bee, and are of an exceptionally bright golden-brown colour, due to the thick coating of hairs which are of this colour dorsally, on the front of the thorax and of the abdomen; elsewhere they are dark brown and polished. They sleep through the winter, and when they awake in the spring they quickly begin to make in the earth a little tunnel which may run straight down for a few inches, or may take a winding course according to the soil. Near the end, several lateral branches are excavated to form brood cells. In each of these is placed a little pellet of pollen and honey about the size of a pea, in which is laid a single egg. Finally, the mouth of the tunnel is covered up with a little mound of earth and then left. The eggs hatch, the larvae feed on the food provided, and their development proceeds without any further attention on the part of the mother-bee, who indeed dies soon after she has finished her little burrow. The male bee is rather smaller, darker, and duller in colour.

The Leaf-cutting Bee. The Leaf-cutting Bees (*Megachile*) are also solitary, and have rather similar nests, but in this case the bee does not usually excavate the tunnel, but takes possession of cavities which she finds in the wood of tree-trunks—cavities made originally, perhaps, by a wood-eating caterpillar and now deserted—or she may use some convenient crack in a wall, but occasionally she may tunnel in the ground.[1] The bee lines the tunnel, wherever it may be, with a cylinder formed of pieces of leaves deliberately cut by her from a plant, and inside this she makes little thimble-

[1] *British Hymenoptera Aculeata*, by E. Saunders.

shaped cells, one above another, also of leaf fragments (Fig. 321, *c*). Rose-leaves are used by one species of leaf-cutting bee, other leaves by other species. The bee settles on the edge of a leaf and cuts out a piece, as shown in Fig. 321, *a*. She clings to the piece she is detaching, so that when finally it is severed, she flies away with it doubled under her legs. Each cell is formed of several layers of leaf fragments, and in each, as it is finished, are placed a mass of pollen and honey and an

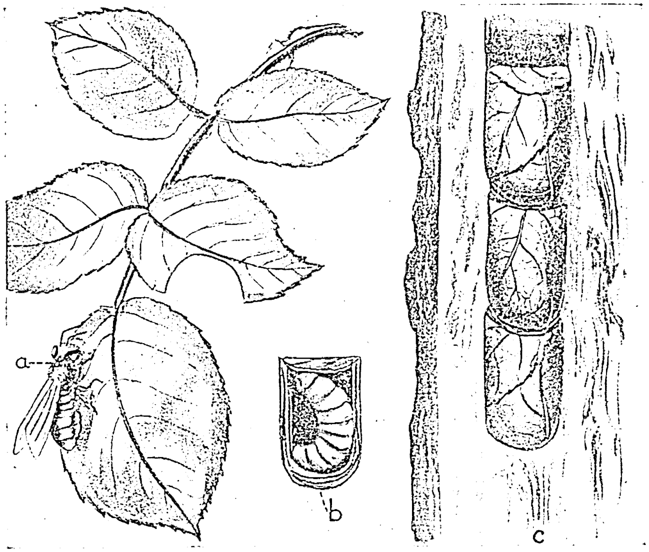


FIG. 321.—The Rose-leaf-cutting Bee.

a, Imago; *b*, one cell opened to show the grub within; *c*, tunnel in a tree-trunk filled by the bee with her thimble-shaped cells. (Slightly enlarged.)

egg; finally a cover to the cell is made of little circular pieces of leaf. Another similar cell is made above the first, and so on until there may be a column of six or seven of them. These solitary bees have all a much shorter proboscis than the hive-bees.

Osmia. *Osmia* is another Bee of the same family as *Megachile*, one species of which (*O. tridentata*) is very common in the South of France. It excavates a series of oval cavities in the pith of bramble stems, building up between successive cells partitions made of partially masticated pith.

Osmia rufa is common in England; it utilises empty snail-shells, constructing several cells within each.

Mason Bees. The Mason Bees (*Chalicodoma*) of the South of France are closely allied to the Leaf-cutting Bees. They construct little hard cells, about an inch deep, of a kind of cement made of earth particles, causing them to adhere by mixing them with saliva; occasionally the cells are strengthened by the addition also of small stones. They are fixed to a large stone as a base, or to a wall in some sunny spot; as each cell is finished, the bee deposits in it an egg, and then cements up the opening. Eight or nine cells may be formed close together, and finally they are covered by a continuous layer of "mortar," which hides and protects them. In *C. muraria*, one of the commonest species, the dome-shaped "nest," when finished, is about as large as half an orange. No species of this genus is known in Britain.

The last three genera mentioned—*Megachile*, *Osmia*, and *Chalicodoma*—are all alike in carrying pollen attached to the hairs on the under side of the abdomen.

These solitary bees are a fascinating study, and a most delightful account of them, as well as of solitary wasps and many other insects, is given by J. H. Fabre in his well-known *Souvenirs entomologiques*, parts of which have now been translated into English.[1]

Classification of Apidae mentioned in Chapter XXVII.

Family. APIDAE.

Sub-family 1. *Sociales*. Long-tongued forms living in communities.

Apis mellifica, the Honey Bee.
Bombus terrestris, the Earth Humble Bee.
Bombus lapidarius, the Stone Humble Bee.
Bombus agrorum, the Moss-carding Bee.

Sub-family 2. *Andrenidae*. Short-tongued, solitary bees, each individual with a separate burrow, but gregarious to some extent.

Andrena, the Burrowing Bee.

Sub-family 3. *Dasygastres*. Short-tongued, solitary bees which construct special cells for their young; pollen

[1] *Insect Life* (Macmillan. Price, 9d.).

is carried on the hairs on the under side of the abdomen.

Megachile, the Leaf-cutting Bee.

Osmia.

Chalicodoma, the Mason Bee (no British species).

Practical Notes on Bees

1. If possible keep bees, or at any rate visit an apiary, and get the bee-keeper to show you the hives and explain to you the care of them.[1] Visit an observation hive, or, better still, keep one,[2] so that you may study in detail the habits of the bees. Notice the different kinds of cell. Find the queen-bee, and mark the treatment of her by the worker-bees. Ascertain whether there are any drones in the hive. Notice the difference in structure and habits of the different castes of bees.

Entice some bees out of the hive with a saucer of honey, and as they feed, mark a few of them with little dabs of different, bright-coloured enamel paints on the top of the abdomen. Remove the saucer, and then note how many visits, to obtain honey or pollen from flowers, each marked bee makes in a day. Notice the colour of the pollen brought back, and see if you can determine what kind of plant it has been obtained from, and whether there are such plants in the gardens near by. Try to verify all the other points of structure and life-history mentioned in the text.

Before the winter the bees in an observation hive must be removed to an ordinary hive, where they can cluster together in much denser masses, and so maintain the temperature necessary for their life. Food must be given them in the winter, if their own honey has been removed from the nest ; a supply of water must be within reach at all times.

If stung, never *pull* out the sting, for in so doing more poison may be pressed into the wound, but scrape it or flick it off from below with the nail of one finger—irritation may be allayed by treatment with cold water, or ammonia, or crushed plantain leaves.

Read *The Lore of the Honey Bee*, by Tickner Edwardes (Methuen).

Make slides of the proboscis, of the different legs, and of the sting from a dead bee, or obtain them from a dealer, and study

[1] See *Bees and Bee-keeping*, by F. Cheshire ; also *The Honey Bee*, by Langstroth (Dadant, 1919).

[2] An excellent indoor observation hive may be obtained from Messrs. J. Lee & Son, 10 Silver Street, Bloomsbury, London, W.C., with an exit fitted through the wall, so that the bees can go freely in and out.

their structure with the aid of a microscope, making careful sketches of each.

2. Study and identify any Humble Bees you see. Hunt for hibernating queens in the early autumn. *Bombus lapidarius* often burrows in a bank, and her presence may be detected by the little heap of fine earth she has thrown out.

In the spring, try to track a queen *Bombus* home to her nest; if possible prepare some artificial nests and attempt to domesticate some Humble Bees, so that you can follow all the details of their life-history.

3. Read *The Nature Book* (Cassell), pp. 805-809, an article by H. Bastin explaining exactly how to take a Humble Bee's nest for observation purposes. Read also the very interesting account of "Wild Bees" given by Benjamin Kidd in *A Philosopher with Nature*, and, in the same book, his chapter on "The Habits and Intelligence of Bees." See also chap. vii. in *The Humble Bee*, by F. W. L. Sladen, which book should also be referred to for the identification of species.

4. Look for *Andrena* in early May when she excavates her burrow on any sunny, sandy bank; when a bee has been seen to enter her burrow, invert a glass over it to catch her as she comes out; examine her carefully. Look for the smaller male bee sometimes to be found near by. Dig down one burrow and determine how it is constructed, and what provision is made for the nourishment of the larvae. Leave a muslin-covered frame over the burrow and note when the new young bees emerge.

CHAPTER XXVIII

INSECTA (*continued*)

Order: HYMENOPTERA (*continued*)

Family: VESPIDAE (SOCIAL WASPS)

THESE Hymenoptera are all characterised by the longitudinal folding over of each of the first pair of wings when at rest, so that they look only half their natural width. The wings are gauzy and transparent. The first segment of the thorax is peculiar and characteristic in shape. It is very narrow, and curves back on each side round the second segment, resting finally on a little scale at the base of the wings, known as the "tegula."

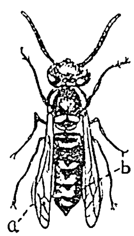


FIG. 322.—Common Wasp. Dorsal view.

a, Folded upper wing; *b*, margin of lower wing projecting from below the upper wing.

Three castes of individuals, males, females, and workers, are to be found among social wasps as among social bees.

The Common Wasp (*Vespa vulgaris*).

Wasps are very well-known insects, for their yellow, black-barred, thin-waisted bodies and fierce buzz make them very conspicuous as they fly about, stealing what food they can get from our tables, and fiercely stinging when interfered with. A sting does not mean death to them as it does to a Honey Bee. However, they are often unduly maligned, for, contrary to the general opinion, they never sting unless worried, and if only we could control our hasty movements of fright when they fly near us, we should

be rarely stung, and could with impunity come to such close quarters with them that we might learn, as did Mr. G. Peckham and his wife,[1] to delight in tracing out their curious ways of life and interesting history. This insect has been called "a tiger-soul on elfin wings,"[2] and the description suits it well, for marvellously in contrast are the audacity and courage of the little, vividly coloured thief and the delicate, minute wings on which it speeds so swiftly through the air.

The Solitary Queen.

As in the case of Humble Bees, only the queen wasp survives the winter, hibernating in some sheltered crevice. On her alone depends the whole possible future colony of many thousands of wasps. She awakes usually early in April, and having cleaned and brushed herself she leaves her hiding-place, and after a hasty meal at once begins to search for a convenient spot where she can found her city, which usually must be safely hidden in the earth, though sometimes it is suspended under the eaves of a house or barn. Very likely she will take possession of some burrow she finds in the earth, and will enlarge it to suit her needs, carrying out the soil bit by bit in her mouth.

Soon she flies off to find some dry, exposed piece of well-seasoned wood, and with her specially powerful jaws she scrapes away a few of its fibres, which she then bites up and mixes with a sticky secretion from her mouth, until it is a pulpy mass (Fig. 323). With this she flies back to her burrow and begins to build.

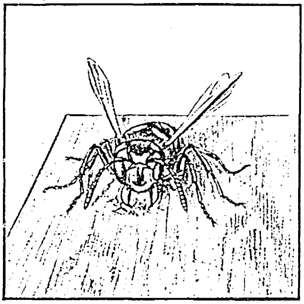


FIG. 323.—A Wasp scraping Wood with her Jaws.

The Beginning of the Nest.

The first pellets of wood pulp she fixes to some firm object, such as a root in the roof of the cavity or burrow in which she elects to build, so that a little pendent stalk is formed; to the end of this she attaches first a small, cup-shaped cover about ½ an inch in diameter, and then, hanging down below it, a little flat platform with three or four shallow, cup-shaped cells

[1] *Wasps, Social and Solitary*, by G. and E. Peckham.
[2] *The Wasp*, Fiona Macleod.

with their open mouths downwards. The pulp with which she builds hardens quickly into a tough, grey, papery substance.

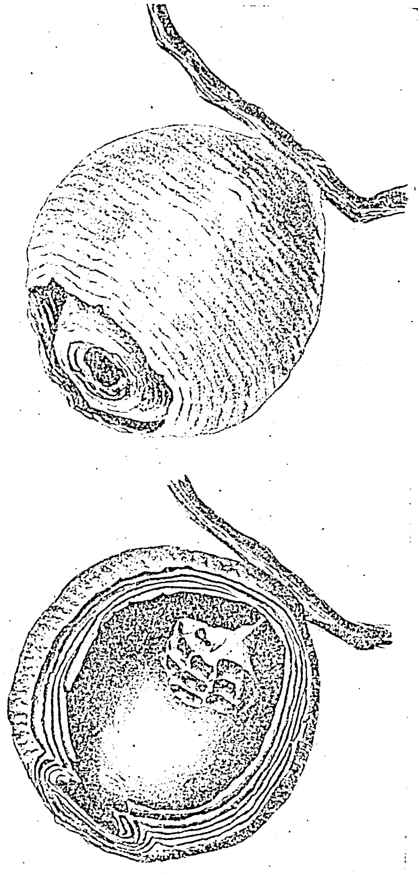


FIG. 324.—Nest of the Tree Wasp, early stage. (Natural size.)

In the lower diagram part of the wall has been removed to show the cells within, and the many layers that form the papery covering.

In each cell she lays an egg, fixing it near the base of the cell, and then goes on to add fresh cells and fresh layers to the papery cap that hangs over them. Fig. 324, which is

really the small nest of a Tree Wasp, shows very well what an early stage of the nest of the Common Wasp is like.

The Grubs. In eight days the first eggs hatch, and now the queen has to be nurse as well as paper-maker, nest-builder, and mother. She goes out quickly to get what food she may, perhaps to steal it from our table, or perhaps to get it from the little chocolate-coloured flower, the figwort, if yet in bloom, or from some other flower specially attractive to her.

Coming back, she feeds her little ones from her own mouth, as they hang head downwards in their cells, preserved from falling by keeping the ends of their bodies still tucked away inside the egg-shells, which are glued to the tops of the cells. They grow rapidly, and she soon has to enlarge their cradles, making them now hexagonal in section. Finally, when about fourteen days old, each larva spins a cocoon and pupates for ten days.

For a whole month, therefore, after the laying of her first eggs the queen toils alone, but by the end of that time the first batch of workers is fully developed, and they bite their way out of their cells, and almost immediately begin to help. First, however, they need food, and they obtain their earliest meal as full-grown wasps in a curious way, for they go round to all the bigger larvae, and by tapping the heads of these with their jaws they induce each to give out a drop of a liquid which they then eagerly swallow.[1]

The Growing Colony. As more and more workers develop, they relieve the queen of one duty after another, until all that remains for her to do is to add to the population, and she now always stays within the nest and is fed by her attendants.

Now that there are many to labour, the community grows apace. Work commences before 5 A.M. every day and continues till dusk. Tier after tier of fresh brood-comb has to be added, even though the old cells are used again and again. The new tiers of cells are built below the previous ones, and held suspended from them by a central stalk, several extra pillars being added at different points. The original stalk of suspension is also strengthened as new combs are added (Fig. 325).

[1] O. H. Latter, *Natural History*, p. 145.

The Nest. The nest, when fully formed, will be nearly spherical, and, if a large one, may be 16 or 17 inches across each way, and often have seven separate combs with a space about $\frac{1}{2}$ an inch deep between the successive layers. There may be altogether eight or nine thousand

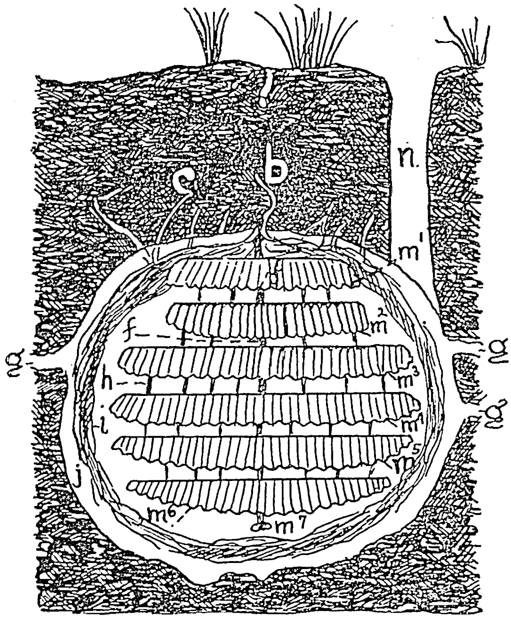


FIG. 325.—Section of the subterranean Nest of the Common Wasp (after Janet). ($\frac{1}{4}$th natural size.)

b, Root to which the first attachment of the nest was made; *c*, secondary attachments; m^1 to m^7, the layers of comb; *f*, chief suspensory pillar of comb; *h*, one of the secondary pillars; *i*, layers of wasp-paper forming the envelope round the nest; *n*, entry to the burrow; *g*, lateral galleries; *j*, vacant space round nest.

cells, which means that at least twice that number of wasps have developed during the season, since each cell is used two or three times. The outer envelope will have been enlarged, and it now covers the whole structure with several layers of "wasp-paper." These help to retain the warmth engendered by the crowds of insects within and which is necessary for the development of the brood. The average temperature of the

nest is about 88° F., *i.e.* often many degrees above that of the surrounding air or soil.[1]

In the subterranean nest of *Vespa vulgaris* only the first cover to the nest, that laid down by the queen, consists of a continuous smooth sheet of "wasp-paper"; after that, little separate plates of this material are plastered on the outside with air spaces below them, like little blisters, and, as these plates are added all over the original cover and then also one above the other, the layer below is cut away and the material worked up afresh to be placed on the outside, or made into new cells. The paper is light brown with white streaks. To make room for the enlargement of the nest, the cavity has had to be laboriously extended, each particle of earth being carried out of the nest and dropped at some distance from it. There is always a space left round the nest separating it from the earth; down this the wasps crawl, entering the nest itself from below (entrance not shown in Fig. 325).

Food of Wasps.

The larvae are fed by the workers largely on honey, though to some extent on animal juices as well. The adult wasps also like animal food occasionally, and will pursue a fly, sting it to death, and then proceed to cut it to pieces and leisurely to eat all nourishing morsels. Wasps are undoubtedly useful to us in ridding us of many flies, green-fly, caterpillars, and earwigs, which may be injurious to garden plants or field crops.

New Queens and Drones.

In August, cells of a larger size are constructed on the last comb formed, and in these the queen lays some eggs which will develop into queens, probably owing to the special food supplied to the larvae. Subsequently she lays a number of unfertilised eggs that will produce males or drones. By the time these are all fully developed, occasional cold weather is beginning to make the wasps inactive and drowsy, and soon the new young queens, who had been allowed quite amicably to live in the nest with the old queen, leave it, and the drones also go out to find a mate. The queens never return, but, having mated, they seek out their winter quarters, where, if all goes well with them, they will hibernate in solitude until the following spring, each hanging herself up in some crevice, holding by her jaws alone, and

[1] See Janet and Guiot's observations quoted by O. H. Latter in *op. cit.*

wrapping her wings round her body. Owing to a variety of disasters, however, only a small proportion of these queens actually survives.

The Fate of the Colony. As soon as the young queens and drones have gone off, a strange scene is enacted in the hive. The wasps have stored no honey for food, and food is getting scarce. They cease to feed the grubs, which till now they have cared for so constantly, and, as if maddened by their inability to do so, they are said to drag many of them from their cells, carrying them out into the open and leaving them to perish, whilst they themselves either wander outside till the cold kills them, or return to the nest, and there become torpid and soon die of cold and starvation, their queen, the foundress of the colony, dying with them.

The Senses of Wasps. Probably in Wasps, as in Bees, the most sensitive organs of the body are those special organs of *touch*, the antennae, which are used as the means of communication between one individual and another. Here, as in bees, these organs are kept scrupulously clean by means of a "brush and comb" structure on the front leg, through which they are frequently drawn. The sense of *sight* seems to be good. There are the usual large compound eyes, which are kidney-shaped, and also three ocelli; it is not yet known with any certainty how these different eyes function. Wasps, when they first leave their nest, fly round and above it, as if to fix a picture of it in their minds, and then they fly straight off to their destination, taking short journeys at first and gradually extending them.

If, whilst they are out, we take the opportunity of covering the ground round their nest with a square of coloured paper, leaving a hole just over the entrance to it, they will on their return appear greatly disturbed. They will hover around, and hundreds may collect outside, afraid to go in, until at last one enterprising spirit makes the venture and comes out again unharmed, whereupon the rest are reassured and gradually follow the example of the pioneer. In a few days they have got so accustomed to the paper that its removal, and the consequent reappearance of the natural surroundings of the nest, gives them cause for fresh alarm. Testing them with different colours gives indications of a distinct preference on

their part for some colours over others—green seems to be liked best, and then perhaps purple.[1]

The sense of *hearing* does not seem acute, at any rate with respect to the sounds which usually affect us. Some agitation has, however, been caused amongst wasps by playing to them on a comb covered with paper! Perhaps it is the similarity of the noise produced to their own buzzing that excites them. The possession by wasps of the senses of *smell* and *taste* seems undoubted.

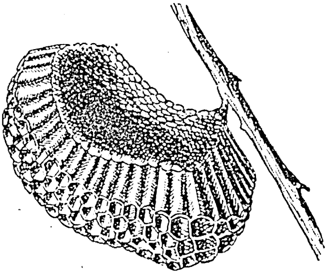


FIG. 326.—Nest of a foreign Wasp, *Polistes*. (Natural size.)

There are several other common species of *Vespa* which are very similar in their appearance and habits to *Vespa vulgaris*, some forming similar nests underground, some suspending their nests from the boughs of trees.

V. germanica is rather larger than *V. vulgaris*, and on the sides of its black thorax it has a yellow stripe, the lower edge of which is convex instead of being parallel with the straight upper edge as in *V. vulgaris*; its nest is made of grey paper with shell-like markings outside. *V. rufa*, the Red Wasp, is rarer and is so called because of the red or orange marks on the top of its abdomen; it is the smallest of all our native wasps. In its underground nest is also to be found the rather similar *V. austriaca*, sometimes known as the "Cuckoo Wasp" for it appears to lay its eggs in the nest of *V. rufa*; more information, however, is needed about this form.

V. sylvestris, *V. arborea* and *V. norwegica* all suspend their nests from the branches of trees or bushes.

Vespa crabro is the dreaded hornet. It is a larger insect and has a reddish-brown thorax; it constructs a nest of browner, coarser "paper," usually in a hollow tree or under a thatched roof.

Fig. 326 shows the exposed comb made by social wasps of the genus *Polistes*, common in some other countries, but not in Britain.

[1] These statements are based on the interesting experiments performed by Miss C. Isaacson.

Family: Eumenidae (Solitary True Wasps)

There are a number of wasps which lead solitary lives; the ways of these are very curious, and are delightfully described by G. and E. Peckham in their book, *Wasps, Social and Solitary*. The British species, of which sixteen are known, are all alike in having a narrow, black body with yellow bands on it; all have bifid claws on the tarsi, and anterior wings longitudinally folded when at rest, as in the Social Wasps.

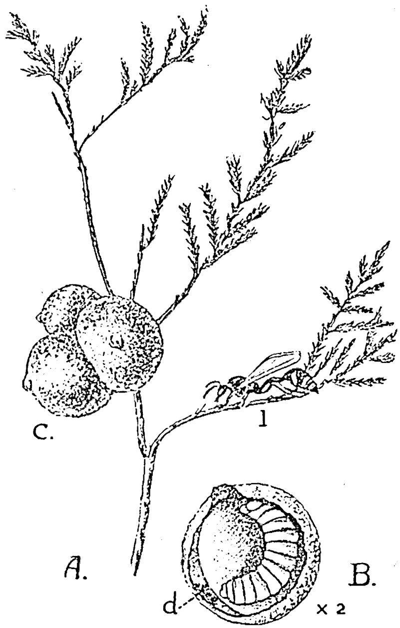


Fig. 327.—A Solitary Wasp (*Eumenes coarctata*).

A, a twig of heather bearing three of the wasps' nests, *c*; *I*, the wasp (nat. size); *B*, one nest cut open to expose the larva within.

The genus *Eumenes* includes several solitary wasps, of which the only British species is *Eumenes coarctata*. This wasp forms little clay, vase-shaped nests attached to twigs of heath or some other shrubby plant (Fig. 327, *c*). The insect itself is easy to distinguish from all other British solitary wasps by its very narrow "petiole" or waist-segment (Fig. 327, *I*). It has stripes and spots of wasp-yellow colour on its otherwise black body.

The nest figured was made of coarse, yellow sand, and was rough and granular outside, but was lined inside with smooth, white silk, and a silken partition ran across the cell, separating off a small, irregular space at one side, in which a certain amount of dark-coloured debris is to be seen (Fig. 327, *B*, *d*), apparently the excreta of the larva.

All our other British solitary wasps belong to the genus *Odynerus*. They have a wider petiole than *Eumenes*, and all live in holes in walls, in wood-work, or in the ground. *Odynerus parietum* is a common British species with very variable black and yellow colouring, sufficiently wasp-like to have gained for it the name of the Wall Wasp (Fig. 328). *Odynerus spinipes* is also fairly common; it is rather larger than *O. parietum* and has narrower, yellow, transverse bands on the body; also on the femur of each of the second pair of legs are characteristic little projecting teeth. This species makes its nest in banks, protecting the mouth of it with a small projecting tube of earth, beautifully made but very fragile. All these solitary wasps provide for their young in a way unlike that of any of the social wasps or bees, for after having laid an egg in the little burrow or tunnel that she has excavated or taken possession of, each mother wasp collects and places in the burrow one, or often several caterpillars which appear partly stupefied, possibly, it is thought, owing to their having been stung before they are stored away, though this does not seem an established fact. On these caterpillars the larvae feed.

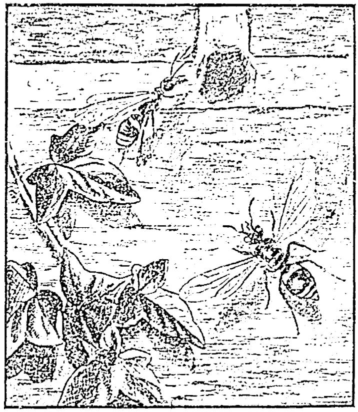


FIG. 328.—The Wall Wasp (*Odynerus parietum*).

Families : POMPILIDAE AND SPHEGIDAE (DIGGING WASPS)

The Digging Wasps differ from the Solitary True Wasps (*Eumenidae*) in certain points of structure, though in habits, and sometimes in coloration, they resemble them. They are therefore classified apart from all the true wasps in the division *Fossores*, of which *Pompilidae* and *Sphegidae* are the two chief families. In these forms, the front wings are not

folded over longitudinally when at rest, and the eyes have not the kidney shape characteristic of true wasps. They all have the habit of burying with their eggs a mass of stupefied insects or spiders to serve as food for their larvae; the individuals of one generation only in rare cases live to see their offspring and yet they make elaborate arrangements for their well-being. Their instincts are complex and wonderful, but intelligence seems lacking; the consideration of the habits of these wasps is one of great interest when the contrast between instinct and intelligence is being considered.

The *Pompilidae*, or "Running Wasps," are sun-loving, red-bodied forms, with a long "pro-notum";[1] they have no well-developed petiole, though the "first" abdominal segment may be slightly narrowed. The hind legs are relatively very long, and these wasps are very active runners; they tunnel little nests in banks and store them with paralysed spiders for their young. *Pompilus viaticus* is a common British species.

The *Sphegidae*, or "Sand Wasps," have a short "pro-notum" and a petiole so narrow that the abdomen often appears stalked. The "Common Sand Wasp" (*Ammophila sabulosa*) buries caterpillars for its larvae in vertical burrows; the yellow and black "Meadow Sand Wasp" (*Mellinus arvensis*) has a rather short petiole; it preys on Diptera. There is a very similar but weevil-killing Sand Wasp (*Cerceris arenaria*), and also many British species of *Crabro*, which usually form their burrows in the pith of stems, in rotten wood, or in the ground, storing them with flies for their larvae. *Crabro* is black-bodied or wasp-like in colouring, and the larvae spin tough, brown cocoons.[2]

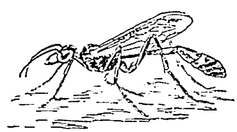


FIG. 329. — The Common Sand Wasp (nat. size) (*Ammophila sabulosa*).

[1] This is the upper part of the first thoracic segment, which is here separate from the side pieces. It may be recalled (see p. 401) that the thorax is united in Hymenoptera with the *first* abdominal segment, and it is really the second such segment that forms the "petiole."

[2] For a most interesting account of *Sphex*, a South European Digging Wasp, see *Insect Life*, by Fabre (Macmillan, 9d.).

Classification of Bees and Wasps mentioned in Chapters XXVII. and XXVIII.

Sub-order. HYMENOPTERA ACULEATA (the Stinging Hymenoptera).

Division 1. **Anthophila** (Family Apidae). Bees with protrusible proboscis, feeding on nectar or pollen; the body hairy, some of the hairs plumose.

(For further classification see pp. 427-8.)

Division 2. **Diploptera**. Wasps having the front wings folded once longitudinally when at rest; eyes kidney-shaped.

Family Vespidae. Social wasps.

Genera. *Vespa*. *Polistes* (not British).

Family Eumenidae. Solitary true wasps.

Genera. *Eumenes*. *Odynerus*.

Division 3. **Fossores**. The Digging Wasps. Solitary, carnivorous forms, front wings not folded when at rest, eyes not kidney-shaped, no "worker" caste.

Family Pompilidae. "The Running Wasps."

Genus. *Pompilus*.

Family Sphegidae. "The Sand Wasps."

Genera. *Ammophila*. *Mellinus*. *Cerceris*. *Crabro*. *Sphex*.

PRACTICAL WORK ON WASPS

1. Hunt for a wasps' nest on a sunny, sandy bank, tracking a wasp to the entry of the nest. Having found one, sit down quietly a few yards from it, and watch the wasps going in and out. Note their mode of flight, in what directions they go, the number entering and leaving the nest within a certain time, and the effect of weather on this number. In the late evening, when the wasps have all returned to the nest, put over it a large sheet of coloured paper in which a hole has been cut which just corresponds with the entrance of the nest, pin the paper firmly down, and then be out before the wasps next morning, and watch the effect on them when they observe the transformation of their front door.

After this paper has been left over the nest for several days, change it, trying the effect of different colours in succession, and also the effect of transferring the last paper, after the wasps have got quite used to it, to a position a yard or so away from the real opening of the nest.

Give a few wasps from the nest a feast of jam, and whilst they are feeding dab some of them on the back of the abdomen with

distinctive, bright-coloured paint, and then keep watch specially on these individuals for a few days. Try to follow certain wasps as they leave the nest, and discover what they do with the pellet of earth they are often to be seen carrying out with them.

2. Destroy a colony of wasps by going out at night when all the wasps are safely inside, and stuffing into the entry of the nest rags soaked in potassium cyanide. Push the rags several inches into the nest with a stick, and then further cover the entry with a sack, on to which throw a few spadefuls of soil. Great care must be taken that none of these rags are left exposed at the surface, for potassium cyanide is a deadly poison.

The next day remove the rags, and dig out the nest very carefully, following down the tunnel from the entry until the nest is disclosed. Most of the wasps will be found to be dead ; some may be only stupefied, and these can be rapidly killed by dropping them into a pot of paraffin and water. The pupae, however, in the cells of the nest may still hatch out, and these and the larvae, whether alive or dead, must be carefully removed from the cells if it is desired to keep the nest. Its structure should be exposed by removing the covering from one side, when a careful examination of it can be made.

3. From the specimens of larvae, pupae, and adult wasps removed from the nest, the different stages should now be studied, careful sketches being made of each, preparations of jaws, legs, sting, etc., also being made for examination under the microscope.

4. In the autumn, a queen wasp about to hibernate may be caught, and if she is put into a box with a piece of muslin pinned in an upper corner, she will fix herself to this with her jaws and hibernate until March.[1] She may then be put into a large box, in which an earth bank has been made, and if well fed with honey, she may be induced to burrow in the bank, and to make her nest there. She must, of course, be supplied with a piece of well-seasoned wood from which to make "wasp-paper" ; as soon as she has begun to build she may be allowed free exit from the box so that she may go out and find her own food. The gradual development of the nest will prove a most interesting study, though eventually the colony may become so numerous that the wasps become a pest

5. Be on the watch for solitary wasps ; study carefully any you see, identifying them by reference to *British Hymenoptera Aculeata*, by E. Saunders. Read *Wasps, Social and Solitary*, by G. and E. Peckham ; also *Insect Life*, by J. H. Fabre.

[1] Leaflet 10 of the School Nature Study Union, *Some Insects and their Habits*, by C. E. Isaacson.

CHAPTER XXIX

INSECTA (*continued*)

Order: Hymenoptera (*continued*)

Family: Formicidae (Ants)

Reference to Bees.

The ordered lives of the communities of the honey bee, and other social bees, are wonderful for their almost ceaseless activity, for the mathematical precision with which the brood-comb and honeycomb are formed by the workers, for their industry in collecting nectar for present and future use, for the strange and utter absorption of the queen—the only mother in the hive—in the work of egg-laying, and for the untiring care of the young by the workers. In fact, we can only marvel at the wonderful instincts which make up the "spirit of the hive," and which have brought this communal life to so great a degree of perfection.

Nevertheless, the lives of these bees are limited in many directions. They have to spend much of their energy in constructing their combs of wax, their food is very restricted, and is not to be found in the winter, when they are dependent on their stores—and to store sufficient food means hard work during the summer. In consequence their lives show little variation from the almost automatic round of cell-making, brood-rearing, and food-getting, and the lives of the workers are short as well as strenuous, rarely lasting for more than twelve months, and often for a much shorter time.

Ants.

Ants also live in large communities, but they have simplified to some extent the material side of their lives; their homes in the earth are far simpler, and

require less expenditure of energy; also they can readily migrate from one place to another if necessary. Their diet is less restricted; they will eat animal and vegetable matter of many kinds, and so their food is far more readily obtained than the bees' restricted diet of pollen and nectar. They have, therefore, more time and energy to spare for other things, and we find amongst them apparently greater plasticity. They have developed much more varied instincts than bees, and have adapted themselves to a more varied existence. In the hunting raids, the herding and harvesting activities, and the crop-growing habits of different ants, we see indications of a higher type of development, bringing these minute members of the animal kingdom nearest to human beings in the organisation of their social life, and in the division of labour amongst the workers of the community.

Type: **The Yellow Meadow Ant** (*Lasius flavus*).

In order to get some idea of the general course of ant life, it may be well first to study in detail the life of such a simple community as that of the Yellow Meadow Ant (*Lasius flavus*), which is common in light, rather moist soil, and forms inconspicuous nests a short distance below the surface. Often the only visible signs of these on the surface are a certain amount of loose earth—sometimes forming a small mound—which has been cast out by the ants as they burrowed, and the many ants to be seen running about, or disappearing down one of the openings. If the nest is traced down from one of these entrances, it is found to consist of a network of little tunnels, the "galleries," with larger cavities, the "chambers" of the nest, excavated at intervals at different levels. In excavating, the ant uses its jaws in scraping away and carrying out the earth, and also in pressing the walls of the galleries to make them firm. The front legs also help in scratching out the soil.

The Inmates of the Nest. If in the summer the ant-hill is turned over gently, it will be found to be swarming with little, yellow, wingless "worker" ants, and to contain also many tiny white eggs, larvae, and pupae, each lying in separate chambers (Fig. 330); these will be at once seized upon by the disturbed workers, and carried away to a place

of greater safety. A further search will also disclose a much larger, brown, wingless ant. This is the queen ant, who is probably the mother of the whole community, and

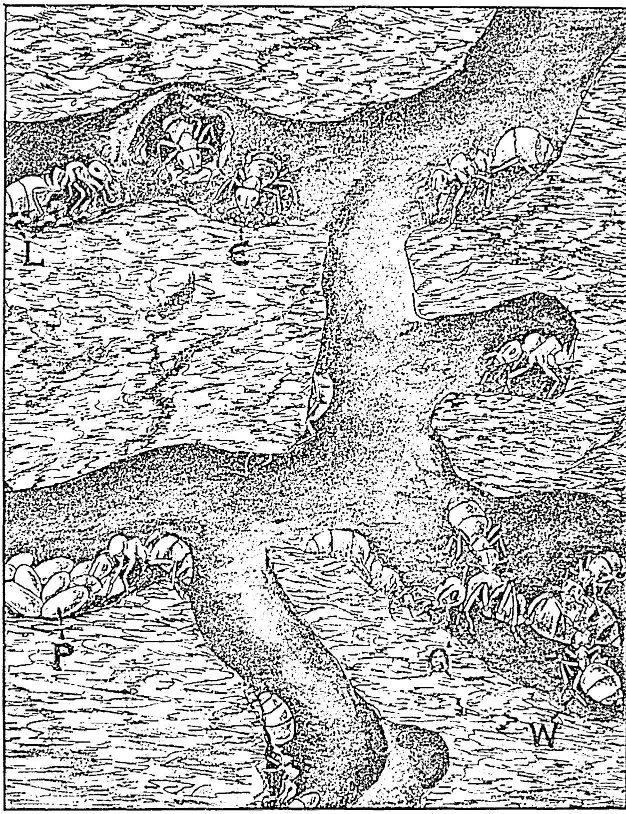


FIG. 330.—Diagram of a section of a small part of the Nest of the Yellow Meadow Ant. (×4.)

E, Eggs; *L*, larvae; *P*, pupae; *W*, worker ants; *Q*, queen ant.

who is now entirely occupied in laying eggs, being constantly tended and fed by the workers. In a large nest there may be several queens (see p. 452).

In the spring, only the wingless queen and her workers will be found in the nest, but in the summer there will

also be many smaller, winged forms, which are the male ants (Fig. 331, *b*), and several young, winged queens, who, however, will not normally lay eggs until they have been out with the males for their "marriage flight," after which they will form new nests.

To study in detail the structure and habits of these ants, the queen, a handful of workers, and some of the brood should be brought home in the spring, and kept for observation in such a nest as that described on p. 470.

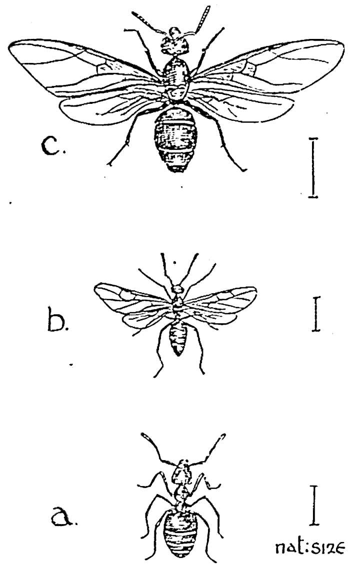


FIG. 331.—The Yellow Meadow Ant (*Lasius flavus*).
a, Worker; *b*, winged male; *c*, young queen.

External Structure (a) The Worker. The workers are usually of two sizes, the larger being shown in Fig. 331, *a*, but the structure is similar in both forms; the division of the body into head, "thorax," and abdomen is very distinct.

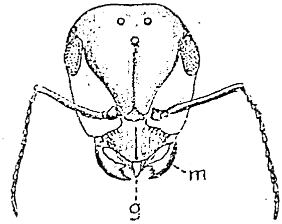


FIG. 332.—The Head of the Wood Ant from in front.
m, Mandible; *g*, tongue.

The *head* bears two compound eyes, each with about eighty facets. In many ants the workers have three simple eyes in addition (Fig. 332), but this is not so in the Yellow Meadow Ant. There is one pair of antennae with an elbow-like joint between the long basal segment and the eleven-jointed terminal part. The mouth is surrounded by an upper lip (labrum), two toothed lateral mandibles, which can be moved independently of the other mouth-

parts, and a pair of lateral soft jaws or maxillae, each provided with a palp and a row of bristles with which the antennae and legs are cleaned. Below the mouth is the labium, also bearing a pair of palps, and a median lobe or tongue with which the ant licks up food and cleans itself and its charges; the duct of the salivary gland opens at the base of this tongue. Just below the mouth and above the lower lip is a little sac-like cavity (the "infra-buccal sac") which opens close to the mouth (for its use see p. 453).

The *thorax* consists of the usual three segments, fused with one abdominal segment, as explained on p. 401. Underneath the three thoracic segments are attached the three pairs of jointed legs always found in insects, and three spiracles are present on either side. The legs, as usual in insects, have four joints and then the five-jointed foot (tarsus), the basal joint of the tarsus being unusually long (Fig. 333). There is a little projecting spur between the tibia and tarsus of each leg, and on each front leg this is specially large and movable, and has a concave inner surface beset with a row of stiff bristles, which faces a similar concavity set with bristles on the first tarsal joint. This structure is known as the "strigil" (Fig. 333), and is used in cleaning the antennae and back legs, which are drawn between the bristled surfaces.

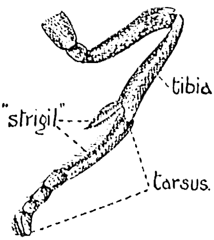


FIG. 333.—The Front Leg of the Yellow Meadow Ant.

The Abdomen.—This term is generally taken to refer only to the swollen hind body or gaster, though, as has been mentioned, part of the true abdomen is really fixed to the thorax, and, as in all ants, the hind body is separated from the "thorax" by a much constricted stalk or "pedicel," formed of one abdominal segment (or "node") in *Lasius*, but of two in many ants (see classification, pp. 468-9). Five segments can be seen externally on the "gaster" when viewed from the side, but only three can be clearly seen from above. Three more segments are to be made out by dissection, but are hidden in life. In many species of ants there is at the end of the abdomen, in both workers and queens, a sting formed of a pair of needle-like, smooth styles surrounded by

two grooved pieces forming a sheath; but these are not developed in *Lasius*, though the poison-gland, usually correlated with such a sting, is large, and opens near the tip of the abdomen. Worker ants, like worker bees, appear to be imperfectly developed females; the ovaries are present though reduced, and eggs are occasionally laid which, although not fertilised, usually develop parthenogenetically into male ants, though recent observations show that this is not always so.[1]

(b) The Queen. The *queen* is much larger than the workers and is of a dark-brown colour (Fig. 331, *c*). Her life is generally much longer than theirs, extending to seven or eight years, while they probably die after two or three years. The thorax of the queen bears two pairs of membranous wings when she is young, though she loses them when she settles down at the head of a colony. Her gaster is relatively larger, and her eyes and antennae are bigger, than in the workers, and she has, besides the two compound eyes, three simple eyes arranged in a triangle in the centre of her head, as in the worker Wood Ant (Fig. 332).

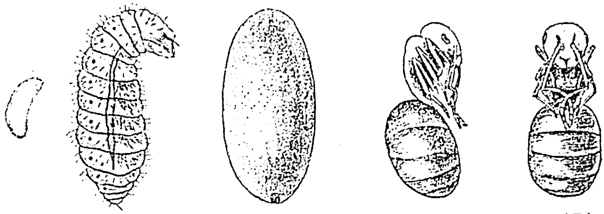
(c) The Male Ants. The *male* ants are also winged, but are smaller in body even than the workers. They have, however, relatively larger eyes and antennae, but smaller jaws. They only appear in the summer, and do not return after the marriage flight to the nest from which they came; they are, therefore, only to be found in the nest during a short period.

Life in the Nest. In the early summer, when no males exist, the *queen* may be found surrounded by workers, who stroke her with their antennae and lick her with their tongues, whilst she stays motionless, or merely responds to their caresses by crossing antennae with those nearest her. At other times, she will walk about the nest dropping minute white eggs, which are at once picked up and carried off by some of her attendants. Sometimes an ant who has been out foraging for food will approach her, and, regurgitating from her own crop the liquid food she has swallowed, will offer it to the queen on her tongue.

The *eggs* are very small, white, oblong bodies about $\frac{1}{25}$ of an inch long; they are carried off by the workers

[1] W. M. Wheeler, *Ants*, p. 71.

to a dark chamber where they are all kept in a little heap, and are daily licked over by their nurses, whose saliva is probably antiseptic and so prevents the growth of fungi on the eggs; it also causes the eggs to stick together, and consequently they can be more quickly removed from one spot to another when necessary.



E L C. P. P.'

FIG. 334.—Stages in the Life of the Yellow Meadow Ant. (×12.)
E, Egg; *L*, larva; *C*, cocoon; *P*, pupa removed from cocoon; *P*[1], pupa seen from in front.

The eggs may vary a little in size and shape, but no distinction has yet been demonstrated between those that will develop into the different kinds of individuals in the nest.

The *larvae* which hatch out from the eggs are soft, blind, legless grubs, narrowest at the head end, which is curved over (Fig. 334, *L*). The soft body behind the head is divided into thirteen segments, and is covered with very fine, white hairs. The larvae have mouth-parts corresponding with those of the adult ant, but as they have no legs and cannot move, they are entirely dependent for their food on their nurses, who feed them on regurgitated liquid. As the larvae grow, and new larvae are hatched out, they are sorted by the nurse-ants according to size, and the different groups are placed in different chambers of the nest. All are kept clean by being licked over regularly, and occasionally they are moved from one part of the nest to another—probably being brought nearer the surface for warmth, or taken to a deeper chamber for more moisture and less light. The workers carry the larvae in their mandibles, picking them up very carefully, and shifting them until they have got them just into the right position.

The Pupa.—When the time for pupation comes, the nurses either bury the full-grown larvae in the earth, or cover them with particles of earth, and each larva then proceeds to spin a silk covering round itself, which is the *cocoon* (Fig. 334, *C*). It accomplishes this by pressing its lower lip against the earth and fixing there a silk thread, which issues from the opening of the spinning gland on the lower lip. It then draws the thread out, and moves its head from side to side, until it has lined the whole of the cavity around it with a web of silk; after this it straightens its body and rests.

The workers now uncover it, and carefully pull away all the earth particles, leaving the larva surrounded only by its yellowish-white cocoon of silk. The larva within soon throws off its larval skin, which is pushed to one end of the cocoon, and if the cocoon is removed the pupa is seen with all the parts of the imago clearly visible (Fig. 334, *P*); the body gradually darkens, the eyes becoming very black; when it is fully developed, the workers cut up the cocoon on one side and help out the new young ant, still rather pale and weak, and known at this stage as a "callow."

A "callow" receives at first a good deal of attention. The workers help her to unfold her legs, and they clean and feed her, but as soon as her skin has darkened and hardened she is left to shift for herself. She does not, however, leave the nest till she is several days old.

The time passed in any one of these stages—and consequently the time taken to complete the development—is found to vary a good deal according to the temperature, and, therefore, according to the time of the year. The larvae which are hatched in the spring become adult ants in a few weeks, whereas those hatched in the late summer spend the whole winter as larvae.

Males and Females.—In midsummer, some of the eggs will develop into winged ants, most of which are males, though a few are females or young queens. The factors which cause apparently similar eggs and larvae to develop so differently have not yet been determined, although it has been shown that underfeeding seems to be correlated with "worker" structure. There is no proof, however, that further differentiation into special kinds of workers, or the development of males and females, is due to special feeding,

such as is thought to obtain amongst honey-bees, and indeed, even in the latter case, as has been said,[1] there is not absolute certainty on this point.

The Marriage Flight. When the new young queens and the males are fully developed, they become restless and try to leave the nest, but are restrained, it is said, by the workers, until one specially favourable day, when they all—queens, males, and workers—come up to the surface, and the winged forms climb up the grass stalks, so as to be able to spread their wings; then away they fly, rising higher and higher until lost to sight. All colonies in the same neighbourhood are said to send out their winged forms on the same day, and they mingle in the air, so that mating takes place amongst members of different families.

The males do not long survive the marriage flight, and do not return to an underground life at all, but the fertilised queens are now only just beginning their careers. Occasionally, after the marriage flight, a queen may alight near her old home and be led back into it by her nurses. More usually she falls to earth to find herself quite alone, and alone she founds a fresh colony.

The Founding of a Nest. The solitary queen first commences action by pulling off her wings, for which she has no further use. She then excavates in the earth a small, single burrow with an enlarged chamber at the end, and closes up the open end. In this hidden retreat she rests for some weeks, until her eggs are mature, when she lays a little batch of them. When the grubs hatch out, she tends them herself, and feeds them on her own saliva. Fed with this food only, they develop slowly, and finally pupate and produce little under-sized workers. It may have taken seven or eight months for the queen to produce and bring up her first small family, and all this time, whilst their whole upbringing depends on her, she takes no food whatever, nourishing both herself and them on the now superfluous substance forming her wing muscles, and on the fat of her own body, which she accumulated during the time when she was a young princess in the old nest, fed assiduously by her nurses.

Soon, however, she is once more to be cared for herself, for before long the new young workers make their way out

[1] See p. 416.

of the ground to the outside world; they bring in fresh food and set to work to feed their mother, after which they at once begin to enlarge the burrow in all directions. As fresh eggs are laid, these workers undertake the whole care of them and the nurture of the larvae.

The queen is able now, therefore, to give herself up entirely to the work of adding to the numbers of the colony, and, fed and tended by her offspring, she may live for many years—an ant queen has been kept alive in captivity for fifteen years. The colony grows in number to thousands, and each year it sends off swarms of winged forms, amongst which are the queens who may form new colonies. The forming of a new colony is, however, obviously an arduous task, and very many of the young queens perish in the attempt.

Occasionally, though rarely, two young queens may alight on the earth close together after their marriage flight, and form a colony together; and sometimes, as has been said above, a young queen will return to her original home, where she is welcomed by the workers and allowed to remain by the old queen; hence, unlike the case in bees, it is not an unusual thing to find an ants' nest with two, three, or even more queens, all equally cared for, and all busily adding to their united colony.

In some species of the genus *Formica* as many as fifty queens may exist in one nest. In such a case there was probably no marriage flight, but the new young queens, their wings having been removed by the workers,[1] were forcibly retained within the nest, the marriage union taking place underground.

The Food of the Ant.

Ants are extremely fond of sweet juices, and for this reason they are friends to certain species of green-fly (*Aphides*), which, when they have been actively feeding, excrete from the end of the body a sweet juice known as honey-dew. (The substance secreted from the two little tubes, which project near the end of the body, is not honey-dew, though it is often mistakenly described as such.[2]) The ant runs after the Aphis, and, by gently stroking its body with her antennae, she induces it to give out this honey-dew, which she then licks up greedily. The special Aphis which the Yellow Meadow Ant favours is

[1] W. M. Wheeler, *Ants*, p. 191.

[2] See pp. 318-19.

the colourless species which feeds on roots. The ant collects these Aphides and keeps them in little flocks, feeding on the roots near its own nest, so that it can obtain honey-dew whenever it is wanted.[1] Some ants go even further than this, for they have been known to collect, in October, the eggs of Aphides which livé on plants above the ground, and to carry them down into their nests and tend them as carefully as their own eggs all the winter until the following spring; then the young Aphides which have hatched out are brought by them to the surface, and deposited on the food plant they need, where they can be visited by the ants when hungry.

Most ants feed also on any animal matter that comes in their way, such as a dead fly, and probably the Yellow Ant will vary its diet in this way at times, though it seems to live mainly on nectar and honey-dew.

When feeding on anything solid, the ant first packs it into a little pocket lying below the mouth (see p. 447), and here all the juice possible is squeezed out of it and is swallowed, for only liquid matter can pass down the very fine oesophagus leading to the "crop," which is situated just beyond the "pedicel" or waist. The solid residue is ejected from this "infra-buccal" pocket later (cf. p. 467).

As a rule only some of the ants go out to forage, and on their return they feed the queen and the nurses who have stayed in the nest to look after the eggs and larvae. It is a curious sight to watch one ant feeding another. When the

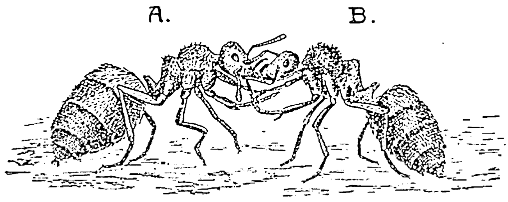


FIG. 335.—*Lasius flavus.* (Much enlarged.)
One Ant, *A*, feeding another, *B*.

forager returns, a hungry ant runs up to her and begins rapidly stroking her cheeks and head with her antennae as if begging for food; the forager then opens her mandibles

[1] Lubbock, *Ants, Bees, and Wasps*, p. 72.

wide and protrudes her tongue, regurgitating food from her crop into her mouth; the hungry one then excitedly presses up to her and begins licking up the food off her friend's tongue, all the while continuing to stroke her, lifting her front legs and holding on to those of her companion, which are also raised, so that they stand in the position shown in Fig. 335. This feeding may continue for as long as five minutes, during which time other hungry workers may come up and try to get a turn. The moment the first has had her fill, one of these rushes in and attempts to get a second meal from the forager, who sometimes, however, refuses it, shutting her mandibles and running off.

As soon as they have fed, the workers busy themselves with cleaning their antennae, passing the front leg right over them, and then drawing them through the "strigil" (page 447). They are very dainty in their toilet, and keep their bodies perfectly free from dirt by regular lickings and brushings.

Life in the Winter. During the coldest months of the year the ants retreat farther underground, occupying only the lowest parts of their nests; there they remain in a semi-torpid condition without feeding until the spring, a large number of the workers always clustering round the queen as if to keep her warm.

The Senses of Ants.[1]

The Sense of Sight. Though ants have two complex compound eyes and often three simple ones as well, their power of sight is probably very limited, for their eyes do not seem adapted for producing clear images of external objects. The compound eyes, according to Exner's[2] view, form a single, upright, much-reduced image of an object, and the more convex the surface of the eye, and the greater the number of facets in it, the clearer is this image; if this is so, the specially large convex eyes of the male must be particularly valuable as enabling him clearly to see the flying queens.

The simple eyes, or ocelli, on the other hand, probably form a reversed image on the retina, as in our own eyes, and

[1] See *The Senses of Insects*, by Auguste Forel (published in English, 1908).
[2] *Die Physiologie der facettirten Augen von Krebsen und Insecten* (1891).

if both sets of eyes are in use at once confusion is suggested. However, it may be that these ocelli are only used for objects very close to the eye, whilst the compound eyes alone are used when looking at objects farther off.

Undoubtedly ants are very sensitive to light, specially disliking blue and violet light, as has been shown by Lord Avebury's experiments, in which he covered a formicarium with strips of different-coloured glass, and found that the ants always removed themselves and the brood from under violet glass, and took up their position by preference under the red, though some were also to be found under the green and yellow strips. They would, however, collect under the violet strip rather than be exposed to full light under plain glass. Lord Avebury from his experiments also came to the interesting conclusion that ants are very sensitive to the shorter waves of light which extend beyond the blue end of the spectrum, and he suggests that they may, therefore, perceive a colour which is unknown to us, which would make their view of things very different from ours.

The Sense of Hearing.

Ants seem to be quite oblivious to sounds within our range of hearing, though in many ants, *Lasius flavus* amongst them, a certain peculiar organ has been described[1] on the first segment of the gaster, which is thought to be an instrument for producing a sound of very high pitch. It consists of a number of fine, parallel ridges running across the first gastric segment, which, when scraped upon by the overlapping edge of the segment in front, produce a sound so high in pitch that it is in most cases inaudible to the human ear, but which is probably audible to ants. The existence of special auditory organs to respond to this sound is not yet fully demonstrated, though certain structures ("chordo-tonal" organs) in the tibia of each leg may be auditory in function.

The Sense of Touch.

The sense of touch is highly developed and is of great importance to ants. Sensitive hairs are specially developed on the antennae, the chief tactile organs with which the ant feels object after object as she moves forward, and with which she appears to communicate with her fellows. That they do thus communicate can hardly be doubted if they are watched, especially on an

[1] Lubbock, *Ants, Bees, and Wasps*, p. 230.

occasion when one solitary ant, having found food, returns to the nest, and apparently spreads the news.

Several different actions can be easily distinguished which seem to have special significance. There is the gentle stroking of the face of a forager by an ant supplicating for food, the violent butting with the head and excited waving of antennae when an ant hurries home after finding a store of food, and many other gradations of movement of the antennae, the significance of which is as yet obscure to us.

The Sense of Smell. The sense of smell is also acute, and together with the sense of touch seems concentrated in special hairs on the antennae. As the latter are waved about, probably the ant is learning as much about its environment by the various odours it detects, as by the actual touch impressions. Imagine how much more our sense of smell would mean to us if we could smell with our fingers, and thus be able to investigate the variations in the odour of every crack and cranny of an object. Loss of keenness of this sense is one of the disadvantages of the upright position—which in other ways has given man so many advantages—for the lower animals, with their heads down, can sniff out the messages of the ground which are lost to us. It is probably by this keen sense of smell and power of discriminating odours that ants distinguish their friends from their foes; ants removed from a nest are recognised and welcomed after months of absence.

Besides possessing special sense organs, it is also necessary for the brain to be sufficiently developed to interpret the sensation received, and we find that whilst the worker ants seem to learn much from, and depend much upon, this special "contact-odour" sense, as it has been called,[1] the male ants, with the same sense organs but far smaller brains, are exceedingly stupid, and are unable to distinguish friends from enemies, or to find their way back to the nest if they stray from it.

The Sense of Taste. The sense of taste seems to be located in certain sensory hairs found round the mouth on the soft jaws and lower lip with its palps. Undoubtedly ants have a decided predilection for one food over another.

[1] Auguste Forel, *Ants and some other Insects*.

Memory and Intelligence.

Experiments have been carried out with different kinds of ants which seem to suggest that they certainly possess memory. Forel describes how an ant, having found a good spot for a new nest, perhaps 30 metres from the old nest, returned, and seizing a sister ant, carried her back with her straight to the spot, evidently remembering the desired goal of her excursion. Even more conclusive are the observations which have been made on the red slave-making ants, *Polyergus* (see p. 461). These ants, led by "scout" ants who have been exploring the ground before, go some distance to raid the nest of the little black ant, *Formica fusca,* and carry off the larvae and pupae to their own nest. If the black ants' nest is cleared at the first raid, the slave-makers do not return to it, but if some of the brood is left behind, they will return on the same or the next day to carry it off—which suggests that their action is due to their memory of the spoil left behind on the first raid.

Also it has been shown that some ants can be trained to come and feed off the finger, or to make use of an artificial bridge placed over a water moat round their island nest, and that individuals vary greatly in the ease with which they can be thus taught.[1]

From these and other observations and experiments it appears obvious that ants learn by experience, and possess some kind of memory; but possibly this is merely a matter of association of sensory impressions, and no power of recalling facts may exist apart from this sensory stimulus. That ants have true recollection, or that they have any power of reasoning, is as yet not demonstrated, though this has often been claimed for them by investigators.

They certainly sometimes exhibit a decided individuality, as indicated by the individual dislikes they show. For example, one ant in a colony kept by Forel cherished an antipathy for another ant of an adjacent colony kept on the same table. Three times this ant seized its hated neighbour and threw it over the precipice of the table edge, the persecuted ant being each time picked up and replaced by M. Forel.

Ants react to some stimuli much as higher animals do.

[1] Cp. G. Turner's experiments quoted by W. M. Wheeler in *Ants*, p. 537.

They are made bold by success, and sometimes are so demoralised by failure that a pugnacious colony will turn arrant coward, and flee before a handful of much weaker ants. Also in their apparent devotion to the welfare of the nest they vary considerably, and all these points tend to show a plasticity which is usual where intelligence is at work.

Other Inmates of the Nest. Besides keeping in their nests flocks of Aphides, which supply food for the colonies, ants tolerate, and even in some cases seem to welcome other, very varied inmates.

In the nest of *Lasius flavus* we find two kinds of little white creatures that wander about, tolerated or unnoticed by the ants; these are:—

(1) A little white wood-louse with very short antennae —and a very long name!—*Platyarthrus Hoffmannseggii*, which strolls slowly about the nest, ignoring the ants and their larvae, feeding probably on the refuse of the nest, and so acting as a scavenger (see p. 192).

(2) Another tiny, white, blind form, a wingless insect allied to the "Springtails" (see p. 237) and known as *Beckia*. This also is ignored by the ants, but seems to be really of use to the colony in scavenging. These are often present in numbers in the nests, running actively about.

Then also *Lasius flavus* allows in its nest, and indeed treats with great favour, a yellowish-coloured, small, blind beetle (*Claviger testaceus*), characterised by its small wings and club-shaped antennae of very few joints. On the body of this beetle are yellow hairs which secrete some volatile substance much loved by the ants, who are constantly to be seen licking it off. Wasmann suggests, from the fascination this substance has for the ants, that it must affect them much as a good cigar affects a smoker! It is, however, rather a dangerous fascination for the ants, for the beetle, though fed regularly by its hosts with regurgitated food, nevertheless is said often to eat the ant larvae. In spite of this the ants cherish the assassins, feeding them, often carrying them about in their jaws, and even allowing them to ride on their backs!

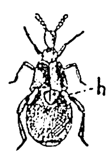


FIG. 336.
Claviger testaceus. Actual length $\frac{1}{8}$ in.
h, Secreting hairs.

In the nests of other ants many other inmates are known. In fact, it is said that as many as 1500 different kinds or Arthropods have been found in ants' nests, about 65 of these being different British beetles. In all these cases the intruders, by living with the ants, get a protected and sheltered home and a plentiful supply of food, and yet but few of them seem to do anything in return, except the Aphides, who supply honey-dew, the scavengers who clean the nest, and the beetles mentioned above which have the secreting hairs. On the other hand, many of the guests are assassins, at times killing and eating the larvae of the ants, and sometimes even the ants themselves.

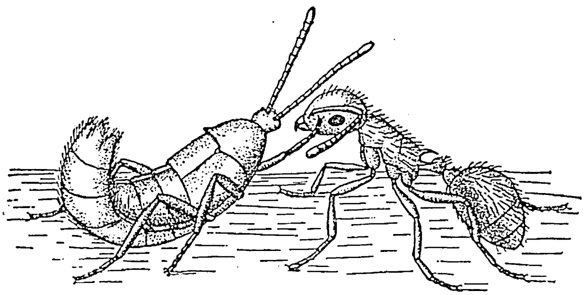


FIG. 337.—*Atemeles*, a parasitic beetle, soliciting food from a worker ant. (After Wasmann, from Wheeler.)

Two of these murderous beetles are *Atemeles* and *Lomechusa*, both belonging to the *Staphylinidae* and so allied to the Cock-tail beetle (p. 281). These beetles are welcomed by the ants, who constantly lick the tufts of yellow hairs on their bodies, caressing them with their antennae, and regurgitating food for them, in spite of which the beetles will eat the ant larvae. The beetle larvae, on the other hand, are nursed and fed by the ants exactly as if they were their own, and this nursing "obsession" on the part of the workers results, strangely enough, in the salvation of the ant colony from the beetles, for the beetle larvae die under the treatment to which they are subjected. The *ant* larvae need to be buried before pupation, and unearthed again a few days later, but to the beetle grubs such a process means destruction; so by the very fact that they make no

difference between their own and their guests' offspring, the ants unconsciously save themselves from being overrun and exterminated by their treacherous pets.

Slave-making Ants. All the inmates so far mentioned have been merely guests in the nest, but some ants keep other ants to work for them as slaves. One species of ant in this country which shows a slight tendency towards this reprehensible custom is the Red Horse or Wood Ant (*Formica rufa*), which builds up over its nest the conical hillocks so common in pine woods, consisting of pine needles, dry leaves, and twigs, rising sometimes to a height of 2 or 3 feet. The winged male and female ants are nearly $\frac{1}{2}$ inch in length: the workers are of two sizes, the larger of them being only $\frac{1}{4}$ inch long. Living in these nests are often found a few of the small common Ashy-Black or "Dusky" Ants (*Formica fusca*), helping in the work of the nest. Their presence may be accounted for in two ways. It is thought, though this has not been quite conclusively established, that the queen of the Horse Ant after her marriage flight often avoids the founding of a new colony entirely unaided, by entering a small nest of *Formica fusca*, and taking possession of it, killing the old queen, and inducing the workers to look after the eggs which the invader now proceeds to lay. In such cases the "Rufa" colony would wax numerous and strong, whilst gradually the "Fusca" colony would dwindle, until finally the conquered race might disappear.

It is also suggested by Lord Avebury that the Horse Ant at times carries off the larvae and pupae of the "Dusky Ant" for food, and that some of the pupae hatch out in their nests, and remain with their captors. However, this is by no means an established custom with this species of ant, as it is with the allied Blood-red Ant (*Formica sanguinea*), which is occasionally found in the South of England, making its nest in a bank, though it is by no means common in this country, as it is in other parts of Europe. This ant regularly makes raids on the nest of the smaller Dusky Ant (*Formica fusca*), or of another closely allied species, and carries off the brood, rearing it and keeping the adults to help in the work of the nest. These forays take place usually in the morning, the ants marching in a rather straggling order direct to the nest to be raided. They gradually surround it, and when all have

arrived they enter and carry off the larvae and pupae, only attacking the defenders of the nest if they actively resist. Though this slave-keeping habit is well marked, the slave-maker, the Blood-red Ant, is still active and largely independent of its slaves, who only form a fraction of the whole colony, and indeed in some cases are entirely absent.

A European ant which is allied to *Formica* but is not indigenous in England, the Russet or Amazon Ant (*Polyergus rufescens*),[1] is a much more degenerate slave-owner, for here practically all the work of the nest is left entirely to the little dusky slaves (again usually *Formica fusca*); the lazy owners no longer even clean or feed themselves, and will starve if the slaves do not feed them regularly—indeed the food must be actually put into their mouths for them. Only when they are going out to pillage, raiding a nest for more slaves, are they active, and brave, and clever. On some July or August afternoon they will wake to energy, and start out in a compact column. Huber describes one such column, which occupied a space 8 to 10 feet long, and 3 or 4 inches wide, with eight to ten ants walking abreast. They hurry along, and having reached a nest of *Formica fusca*, which usually seems to have been previously located by scouts, they drive off any ants that resist them, and swarm into the nest, soon emerging again, each ant carrying a pupa or larva. If attacked by the rightful owners of these, they kill their opponents by piercing them through the head or thorax with their sickle-shaped mandibles. They carry their booty to their own nests, and hand it over to the slave-nurses; and then they themselves lapse once more into inactivity. If isolated from their slaves they will die in a few days, but Lord Avebury found that he could keep them alive for months if he admitted a slave ant to them for an hour or so a day to clean and feed them.

Harvesting Ants. Some ants which live on vegetable food alone, have learnt to store up seeds and grains for food during the winter months. Certain of these ants live on the shores of the Mediterranean, and these seem to have been the first ants to be considered worthy of study; mention of them is frequent in old classic writers, and it is to them, doubtless, that Solomon refers when he says:

[1] P. Huber, *Recherches sur les mœurs des fourmis indigènes* (1810); A. Forel, *Les Fourmis de la Suisse* (1874).

2 H

"Go to the ant, thou sluggard, consider her ways and be wise; which, having no guide, overseer, or ruler, provideth her meat in the summer and gathereth her food in the harvest." Our northern ants have not acquired this habit, and, during the eighteenth and early nineteenth centuries, much doubt was thrown on the subject by the naturalists of northern Europe. However, the facts are now established, and a very interesting account of them is given by J. T. Moggridge, who studied the two species *Atta barbara* and *Atta structor* [1] at Mentone from 1871 to 1873.[2] He saw the ants hard at work collecting the seeds from the various plants, and carrying them back to their nests. They broke off the seed vessels, usually by twisting their stalks or sometimes by biting them; they then picked up the seeds with their mandibles and carried them off home. There were two continuous lines of ants stretching from the plants that were being stripped to the nest, those of one line laden with grains hurrying to the nest, those of the other, empty-mouthed, hurrying out to get fresh stores. In one case the double line he noted was 24 yards long. Before the seeds were stored, the husks were stripped off and thrown into a heap outside the nest, and the naked seeds or grains were then carried to specially prepared "granaries." These differ from the ordinary chambers of the nest in having much firmer, more compact walls, and it is suggested that it may be due partly to the texture of these walls, which exclude air to a large extent, that the seeds stored do not germinate; possibly also the moisture present is not sufficient for germination. If the seeds are damped by heavy rain, the ants bring them to the surface, and dry them in the sun, and then carry them below again. Occasionally some damp seeds are overlooked, and begin to sprout; the ants then bite off the radicle and dry the seed. Sometimes these seeds are left on the "kitchen midden" outside, or occasionally seeds are dropped when being brought in, and so it is frequently found that seedlings of different kinds spring up round the nest, and in this way ants play a definite part in the dispersal of plants. In collecting the seeds, paths are sometimes very regularly made, radiating from the nest in various

[1] Called by Wheeler *Messor barbaris* and *Messor structor*.

[2] *Harvesting Ants and Trapdoor Spiders* (1873), by J. T. Moggridge.

directions; this is very marked in the harvesting ants of Texas, which have been described by H. C. McCook. No harvesting ant is known in Britain, though the little black garden ant (*Lasius niger*) has been noticed occasionally carrying violet seeds into its nest.

Ant Battles. Some of these harvesting ants are very pugnacious, and are inclined to plunder one another's granaries. Moggridge describes a warfare which continued for several weeks between two nests of *Atta barbara*, the stronger constantly robbing the other of its store of seeds. The rightful owners would stop the robbers as they made off with their plunder and a fierce fight would ensue, in which even the loss of half its body did not daunt a fighter, though the seizure of an antenna seemed always to result in immediate surrender.

Honey-storing Ants. A far more curious instinct than that of harvesting is seen in those colonies in which specialised individuals store up nectar and honey-dew in their own enormously enlarged crops for the use of the others. This habit is most developed in the Honey Ants of the "Garden of the Gods" in Colorado, which have been fully described by McCook, but a similar habit has been observed in ants of the dry plains of South Africa and Australia, where food may be very plentiful for a short time and then become very scarce.

Amongst these Honey Ants, some of the workers spend nearly their whole lives hanging from the roughened ceilings of special store-rooms (Fig. 338), being fed by the others when they come in bringing them supplies of honey-dew, until their gasters are almost globular; then in times when food is scarce the workers come to them and are fed from their abundant store. Fig. 339 shows one such "honey-pot" ant feeding a large ordinary worker of the same species, two smaller workers waiting their turns, one on either side.

The "honey" is obtained in these cases, not from *Aphides*, but from the sweet juices exuded from certain galls found plentifully on small oaks in the neighbourhood of the nest.

Driver or Hunting Ants. Driver Ants are very common and very conspicuous in the Tropics. One West African species (*Dorylus* (*Anomma*) *arcens*) described by T. S. Savage[1] forms no nest, but the ants wander from place to

[1] *Trans. Ent. Soc. Lond.* v. pp. 1-15.

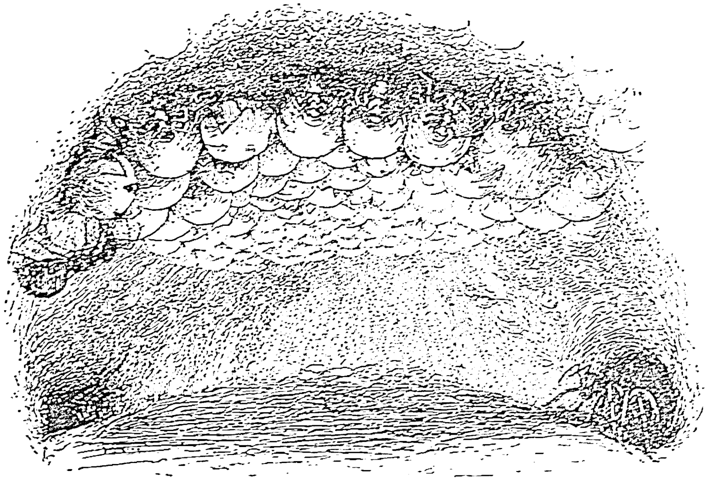


FIG. 338.—Honey Ants (*Myrmecocystus horti-deorum*). (After McCook, from Wheeler.)

From the roof hang the honey-storing individuals; two normal workers are approaching them to be fed.

FIG. 339.—Honey Ants (*Myrmecocystus horti-deorum*). (After McCook, from Wheeler.)

One honey-storing individual feeding three normal workers.

place, sheltering under stones, in crevices in rocks or in the soil. They dislike light, and travel at night or on a cloudy day. If overtaken by sunlight when no shelter is at hand, they construct tunnels of mud, made to adhere by being mixed with saliva, and they move onwards sheltered by these. They feed on any desirable animal food they overtake on their raids, killing animals many times their own size. Moreover, they enter any promising house they come across, and drive before them all the various uninvited inmates of the house, such as mice, cockroaches, lizards, etc., eating everything they fancy, whether it be any of these vermin, or any meat that they may find. They may clear a house of vermin, but their invasions are not altogether welcome to the rightful owners, who appear to be driven at times to sitting on their beds, with the feet of the bedsteads in basins of vinegar to isolate them, until their uninvited guests have come and gone! It is a curious fact that, although they live so much above ground, the workers of these ants are totally blind, and they find their way only by the "contact-odour" sense of the antennae (see p. 456). The workers vary greatly in size, one set forming the "soldier caste" with strong, toothed mandibles, others being much smaller and with small mandibles. They act in common, to a large extent, and Savage describes how he watched a colony, which was camping on a tree, form a rope of living ants, over which the others passed up and down from the ground to the lower branches. The rope was as thick as a man's thumb, and was formed from above, the first ants climbing the tree-trunk, and then hanging from a bough, whilst others passed over them and hung on to their legs, and so on until the rope nearly reached the ground, when the last ants caught hold of a leaf of a plant on the ground, thus completing the ladder or bridge and holding it firm.

Another use of the habit of clustering together appears in times of flood, when the larger workers cluster in a ball, with the pupae, eggs, and other members of the colony in the centre, and float in the water until they reach some foothold of dry land.

Varieties of Nest.

Most ant-nests in temperate regions consist simply of galleries and chambers excavated in the earth, but in the Tropics nests are frequently found hanging from the branches of trees, looking, it is said, like

large bath sponges. These are formed of earth or of a woody or papery substance made of particles of plant-tissue glued together with a secretion from the mouth.

Other small suspended nests are made only of silk, or of leaves bound together with silk, such as the nest of the common ant in Central Africa (*Oecophylla smaragdina*). These nests are especially interesting because of the very strange way in which they are constructed. No adult insects known have the power of spinning silk, though their larvae frequently possess it, and in order to make their silken nests, the adult ants exploit the silk-spinning capacity of their grubs. They seize a grub, and hold it out with the head forward, pressing this gently against the leaf, or whatever it may be to which the nest is to be attached, and then pull the larva away (Fig. 340). A very fine silk thread is then drawn out from its mouth, and this thread is attached again by once more pressing the head of the grub against some object; the process is continued until the whole web is woven. In the case of some foreign Aphid-keeping ants, their larvae are actually carried some distance to the Aphid herd, and there used in building a silken shed over the Aphides.

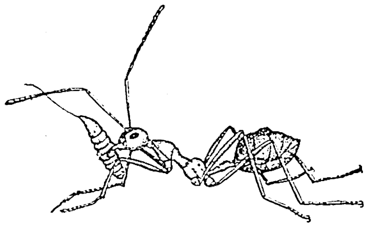


FIG. 340.—The Worker of an Ant (*Oecophylla smaragdina*) using a Larva as a silk-producer when making its nest. (After Doflein, from Wheeler.)

Many ants which live above ground, instead of making their own nests, take advantage of the hollow cavities which occur in some plants. They take shelter in these cavities, and as in some of these plants extra-floral nectaries happen to be present, the ants in such cases find a ready-made home with food provided.

Leaf-cutting and Fungus-growing Ants.

The Leaf-cutting Ants of tropical and sub-tropical America, belonging to the genus *Atta*, present perhaps the most marvellous development of any of the ant family, for they undoubtedly cultivate a special fungus crop for food.[1] In the first place

[1] T. Belt, *The Naturalist in Nicaragua*, 1874.

they form an underground nest with many large, well-ventilated chambers. Then they sally forth and begin to cut large pieces out of the leaves of adjacent trees, carrying these back to the nest, where they are cut up into small pieces, making a loose, spongy mass. This is then made to adhere to either the roof or the floor of the chambers, different species of ants having different customs in this matter. The whole mass is soon held together by the white threads (*hyphae*) of a fungus which develops rapidly in the leaf pulp; after a time the hyphae produce at their tips small white bodies. It is for the sake of these, apparently, that the fungus is cultivated, for they form the only, or at any rate the chief, food of the ants; moreover, it is apparently only when tended by the ants that these little white heads are formed. As soon as the fungus is well developed in the spongy masses, the larvae are distributed throughout it and are fed on it.

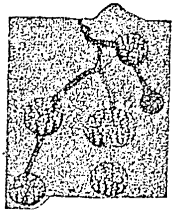


FIG. 341.—Five Chambers from the nest of a Leaf-cutting Ant in which the white fungus is growing (reduced). (After Wheeler.)

The way in which these fungus-gardens originate in new colonies has recently been brought to light.[1] It has been shown that the young queen, when she goes out for her marriage flight, has always in her infra-buccal pocket (see p. 447) a little pellet of the fungal food, and that when she founds her new colony she ejects this pellet, and with it starts her vegetable garden the day after she enters the earth. On the third day she lays her eggs, and for the next five or six weeks she divides her time between egg-laying, cleaning and nursing the little grubs that hatch out, feeding them on other eggs, and tending her kitchen-garden, apparently watering and manuring the fungus with secretions from her own body. By the time the first batch of workers appears, the fungus is in a condition to be eaten, and it forms their food, though they still feed the larvae on eggs. Finally, about seven weeks after the founding of the colony, some of the workers make their way out of the earth, and begin

[1] A. von Ihering, *Die Anlage neuer Colonien und Pilzgärten bei Atta sexdens* (1898).

to bring in fresh leaves on which to grow fresh fungus threads. From this time onward the larvae are only fed on the fungus, and the queen leaves off her horticultural efforts and gives herself up entirely to increasing her family.

Some of these leaf-cutting ants, such as *Atta texana* of Texas, do an enormous amount of harm to the plants around the nest. This species has three kinds of worker ants—the smallest appear to spend their time tending the fungus beds, keeping them carefully weeded of any other growths; the medium-sized forms go out and cut the leaves and prepare new beds of them, whilst the larger ants guard the nest.

The accounts of these fungus-growing ants given by different investigators read like fairy tales, and yet they have been vouched for again and again by competent observers, so that we can but accept them, and wonder over them, at the same time bearing in mind the words of the old Dutch writer Swammerdam, who, writing over two hundred years ago, said: "I can only recommend it to every one who shall be desirous of knowing the truth, to consult the insects themselves, for nature far surpasses all the writings and treatises that may be compiled."[1]

Classification of the Ants mentioned in Chapter XXIX.

Sub-order. HYMENOPTERA ACULEATA (the Stinging Hymenoptera).

Division 4. **Heterogyna** (= Family: Formicidae). Social forms, always with differentiation into three castes of individuals, males, females, and workers.

The first, or first two, abdominal segments—not reckoning that segment which is fused with the thorax—form "nodes," small knot-like segments, with very mobile articulation.

Sub-family 1. *Camponotides*. One node only is present, bearing a flat, elevated scale. There is no sting, though poison can be ejected from the modified sting structure.

Pupae usually enclosed in cocoons.

Genera. *Formica*.
- *F. sanguinea* (the Blood-red Slave-making Ant).
- *F. rufa* (the Wood Ant or Red Horse Ant).
- *F. fusca* (the Dusky Slave Ant).

[1] J. Swammerdam, *The Book of Nature*, 1758.

Lasius.
- *L. flavus* (the Yellow Meadow Ant).
- *L. niger* (the Common Black Garden Ant).
- *L. fuliginosus* (the Jet Black Ant, inhabiting old posts or rotten trees).

Polyergus. The Russet or Amazon Slave-making Ant of Europe (not British).

Oecophylla. Native of Asia (not British).

Myrmecocystus. The Honey Ant of America.

Sub-family 2. *Myrmicides.* Two nodes are present, and a well-developed sting; pupae always naked.

Genera.
- *Myrmica.* *M. rubra* is the only species common in Britain.
- *Atta* (= *Oecodoma*), the Leaf-cutting Ant and Harvesting Ant (not British).

PRACTICAL NOTES ON ANTS.

1. The Yellow Meadow Ant (*Lasius flavus*) is perhaps the best kind to keep for preliminary observations on Ant life.

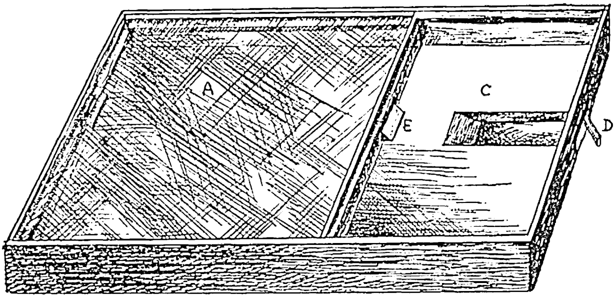


FIG. 342.—An Observation Nest for Ants, uncovered and seen from above. *A*, "Nursery" chamber; *C*, playground room; *D*, opening of food trough; *E*, sloping passage leading from *A* to *C*.

This ant is common in light soil, and it is not difficult, with a trowel, to dig away the nest until the inner chambers are disclosed. The queen may be hidden at a depth of 2 or 3 feet from the surface. She should be very carefully searched for, and, when found, transferred with a number of workers, pupae, larvae, and eggs to a box partly filled with the fine earth of which the nest was made. Later on the ants can be gain moved, this time into the special nest which they are to inhabit for some months.

This observation nest or "formicarium" should be constructed[1] so that there is one chamber (the "nursery" chamber, Fig. 342, *A*) which is formed of two horizontal sheets of glass, separated only by a space about $\frac{1}{8}$ inch deep which is filled with finely sifted, damp earth from the original nest; in this narrow layer of soil the ants can burrow without ever being able to hide themselves. Communicating with this chamber is a larger one with a wooden bottom and a glass roof, the space between the two being as much as an inch. In this "playground room" (Fig. 342, *C*) little banks of earth can be made, and small tufts of grass or other plants introduced. In it is also a small trough for honey or other food.

Such an extra deep room is desirable, not only because it affords the ants scope for freer, more natural activities than the confined space of the "nursery-room," but also on account of the ease with which a new colony of ants dug up from the garden or field can be introduced into it.

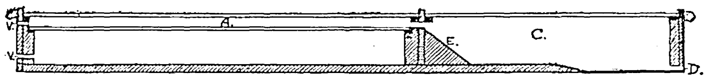


FIG. 343.—Section across the Nest shown in Fig. 342. Lettering as before.

In preparing the nest for the new colony, care must be taken that the narrow passage between the two chambers is not blocked; also it is desirable to make a path in the soil, leading from the entrance into the centre of the "nursery." This chamber is then darkened by a cover being placed over its glass roof, and it is thus rendered attractive to the ants who, as a rule, shun the light. The colony of ants which has been obtained is now introduced into the undarkened "playground" chamber, the queen being gently lifted with a camel's-hair brush. Very soon some of the ants will discover the entry to the darkened part of the nest, and will enter it and explore. They will then return and apparently communicate their find to some of the other ants, for more will now accompany them to explore again. Finally they will approach the queen and stroke antennae with her, after which, in some cases, she will go willingly with them to the new home. In other cases the workers seem to use force; one or two will seize her mandibles with their own and pull her along, whilst others apparently push her from behind. When once the queen is safely in,

[1] See Appendix E for a simpler type of Formicarium designed by Mr. Hugh Main.

some workers stay with her, but the others in great haste return and begin to collect eggs, larvae, and pupae, and bring them also into the dark. In an hour or so the light room will be deserted, and the ants will all be very busy caring for the transported young, cleaning and feeding them, and excavating in the earth special chambers for them. Now the empty room may be arranged attractively, and food introduced, either a drop of honey, or a dead fly, or a piece of banana skin, and then a dark cover should be left partly covering this part of the nest also, so that the ants may be tempted to come back to feed.

The further care of the nest will consist in keeping the store of food replenished, and also in taking care that the earth does not get dry. Every week it will probably be found necessary to let a little water run in through a door left for this purpose in the nursery chamber. If a more thorough sprinkling of water, or re-arranging of the earth, is necessary, the ants can all be induced to go into the playground, carrying the young with them, merely by exposing the nursery chamber to bright light, whilst the playground is kept dark.

Various experiments may be tried in such a nest, *e.g.* strips of different-coloured glass may replace the uniformly dark cover in general use, and so the preference of the ants for certain colours ascertained. Root *Aphides*, or the special beetle pets favoured by the Yellow Meadow Ant, may be introduced, and their treatment by the ants watched ; and other experiments, such as those described by Lord Avebury in *Ants, Bees, and Wasps*, may be repeated.

2. The Common Wood Ant (*Formica rufa*) should also be kept for a short time in a special observation nest, but this nest must be of quite a different type. A box, a foot square, with wooden bottom, glass sides, and a freely perforated zinc top, answers well. A mound should be made of the pine needles, and some thirty ants, with the queen and young if possible, introduced ; but even the workers alone are worth keeping for a time, for they are so large that their methods of burrowing, of feeding, and, above all, of cleaning themselves, can be clearly seen, and are most interesting. They should be drawn in as many different positions as possible.

3. From a dead ant, slides should be made of each leg and of the head, and from these the points of structure mentioned in the text should be verified under a microscope, and illustrative sketches made.

CHAPTER XXX

INSECTA (*continued*)

Order: Hymenoptera (*continued*)

Sub-order: Parasitica.

Family: Tenthredinidae (Saw-flies)

These Hymenoptera are very numerous, and their recognition is economically important, for they are often the cause of serious damage to cultivated plants and trees. Saw-flies differ from all other Hymenoptera in having no constricted "petiole" between "thorax" and "abdomen"[1]; also the females possess at the end of the abdomen a pair of saw-like structures, hidden when not in use, but capable of being protruded to make an incision in the plant in which the eggs are inserted.

Saw-fly Larvae. The larvae feed on plant tissues, and in appearance they frequently much resemble Lepidopterous caterpillars, and are often mistaken for such. Usually, however, they can be readily distinguished by the fact that, as well as the jointed thoracic appendages, they have six to eight pairs of "pro-legs" on the abdomen (Fig. 344), whilst true caterpillars have only five pairs at most (Fig. 164). One pair of these pro-legs in saw-flies is connected with the fifth body-segment, a segment which is always destitute of appendages in Lepidoptera; also the pro-legs are lacking in hooks such as are found at the free tip of the corresponding legs in caterpillars. On the head is one pair only of ocelli, instead of several pairs as in caterpillars.

The Pine Saw-fly. Fig. 344 represents some stages in the life-history of a Saw-fly that feeds on the leaves of the pine. The greenish-yellow, black-speckled larva, *a*,

[1] See p. 401 for real distinction between thorax and abdomen.

is shown in one of the curiously contorted attitudes characteristic of it. When full grown, the larva spins a little, oval, brown cocoon, inside of which it remains dormant, for a couple of weeks only, if it belongs to the first brood in the year, but for the whole winter, if it is of the second brood. It changes to a pupa only a short time before the fly emerges.

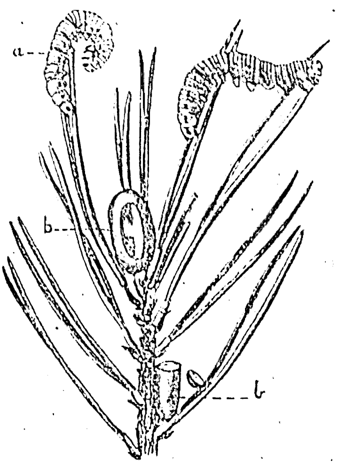


FIG. 344.—The Pine Saw-fly (*Lophyrus pini*).

a, Larva; *b*, cocoons, the lower one open and empty. (Natural size.)

The winter-cocoons are usually formed in the ground, and are larger than the spring ones. The perfect winged insect is not often noticed, as it is quiet and inconspicuous, and the body is only about $\frac{1}{4}$ of an inch long. Fig. 345 represents a male Pine Saw-fly with his characteristic dark-coloured body and beautiful, feathered antennae. The female is more than one-third as large again as the male, and her body is yellow, with dark markings; she differs also from the male in her small, jointed, downy antennae. The eggs are laid early in the year in slits on the Scots pine leaves, six or seven together, and the larvae from this first brood form their cocoons in July. The adults appear early in May and again in August.

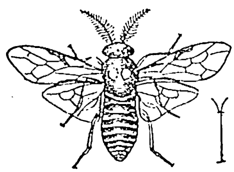


FIG. 345.—The Pine Saw-fly (*Lophyrus pini*), imago, male.

Natural size shown by the side.

The Rose Saw-fly.

Hylotoma rosae is the saw-fly which does so much damage to rose-trees, for its small green larvae (always mistaken for Lepidopteran caterpillars by the uninitiated) destroy the leaf very rapidly. They can be easily distinguished from true caterpillars by their legs, and also by the characteristic way in which they curl up when touched. The action of the

saws as the female lays her eggs is especially easily seen in this species.

Some other Saw-flies.

Other forms equally injurious are the Currant Saw-fly (*Nematus ribesii*) and the Gooseberry Saw-fly (*N. ventricosus*), forms which at times literally strip the bushes of their leaves. The Turnip Saw-fly (*Athalia spinarum*) has small black larvae which do great damage to the leaves of turnip crops.

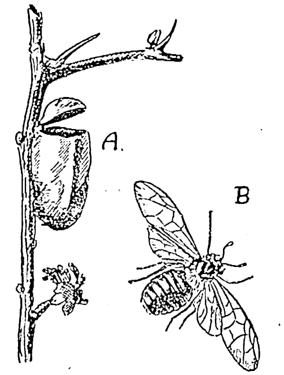


FIG. 346.—The Hawthorn Saw-fly (*Trichiosoma betuleti*).

Trichiosoma betuleti (Fig. 346) is a Saw-fly the larva of which feeds on the hawthorn in July and August; it is green with minute white spots, and on pupation it makes for itself a silky, brown case (Fig. 346, *A*), which is opened at one end when the perfect insect emerges. The fly is covered with reddish-brown hairs, and the tibia of each leg is of a characteristically dusky colour.

Gall-forming Saw-flies.

The larvae of some saw-flies remain within the tissues of the leaf where the eggs were laid, and cause the formation of galls in the leaf, as in the case of the reddish "bean galls" on willow leaves (Plate IV.), caused by *Nematus gallicola*. The larvae when full grown, usually in early November, leave the galls and make their way into the soil, where they become pupae.

The Saw-fly Pea Gall (Plate IV.) is formed by *Nematus salicis-cinereae* on the under side of the leaves of various smooth-leaved willows.

Family: SIRICIDAE

The Wood Wasp or Horn-tail (*Sirex gigas*).[1]

The Wood Wasp is a conspicuous insect which may be $1\frac{1}{2}$ inches long, and is coloured with black and gold bars. It belongs to a family closely allied to the true saw-flies, and having the same sessile abdomen, but it is peculiar in possessing a

[1] See account in Prof. Miall's *Injurious and Useful Insects* for further details.

cylindrical boring apparatus which always projects from the end of the body. The larva lives and pupates in the wood of fir trees, doing much damage. It is rarely found in Britain, though common in some other parts of North Europe.

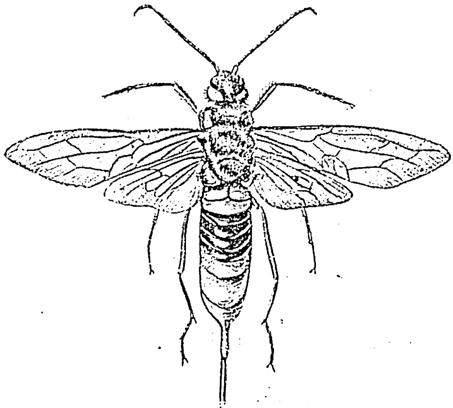


FIG. 347.—The Wood Wasp (*Sirex gigas*). (Nat. size.)

Family: CYNIPIDAE (GALL FLIES OR GALL WASPS)

The Gall Flies are small, dark-bodied forms with long, simple, straight antennae, and with very few "nervures" and no dark patch on the wings. There is a narrow "petiole" between the fore and hind body.

The insects themselves are not usually known to the casual observer, who will, however, probably recognise the galls which many of them cause on the oak and other trees, for such galls are some of the most common objects of the country-side (see Plates IV., V., and VI.). Inside these galls the insects spend the first stages of their lives.

Gall Formation. The galls are formed by the female Gall Wasp. She lays her eggs in the tissues of a living plant, piercing a hole for the reception of each, by means of the long ovipositor she possesses at the end of her body. The legless grub which hatches out begins at once to feed on the soft tissue around it, and the irritation of the cells which is thus caused results in their abnormal, rapid multiplication. The larva and the gall develop together, the former feeding on the inner tissues of the latter.

Internal Structure of a Gall. The tissues of the gall around the hollow cavity in which the grub lies frequently show a considerable amount of differentiation, as in the Spangle Gall. When cut across (Fig. 348), this shows a

layer of nutritive tissue lining the cavity in which the larva lies, and round this a layer of hard, protective cells (*sclerenchyma*), the rest of the gall being of softer, thin-walled cells.

Comparatively few galls are without the hard, inner shell, which doubtless serves to protect the larva within from the attacks of parasites, and from small birds that might try to peck open the gall to get at the grub. The tannin in some, such as the Marble Gall, renders them still more distasteful to birds. Within the gall the larva grows to its full size and pupates. The perfect insect finally bites its way out and flies off. In Plate IV. a Gall Wasp is shown

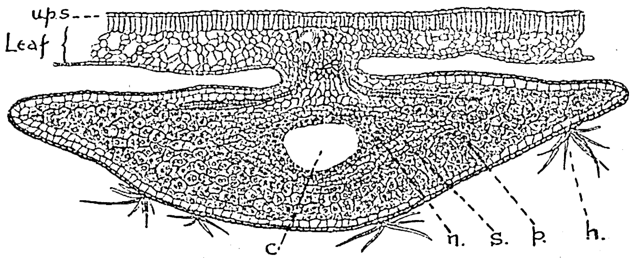


FIG. 348.—Transverse Section through an Oak leaf bearing a Spangle Gall.

up.s, Upper surface of leaf; *c*, cavity in which the gall grub lives; *n*, nutritive tissue; *s*, hard, protective cells (sclerenchyma); *p*, starch-containing cells; *h*, one of the hairs on the surface of the gall.

just about to emerge from the Marble Gall—she is just looking out of the hole she has made. Another is drawn below, enlarged, showing the characteristic, rather clumsy, fat body of the Marble Gall Wasp (*Cynips kollari*).

Cause of Gall-formation. When the egg is laid, a liquid is exuded with it into the tissues, and it used to be thought that this was the irritant that caused the growth of the gall. Since, however, gall-formation rarely, if ever, begins until the larva is hatched, and ceases if the larva is killed, it seems probable that the explanation of the exciting cause is to be found in the activity of the larva as explained above, rather than in the liquid inserted with the egg.

There are many different kinds of Gall Wasps, and each produces a characteristic gall. It is strange that, of all

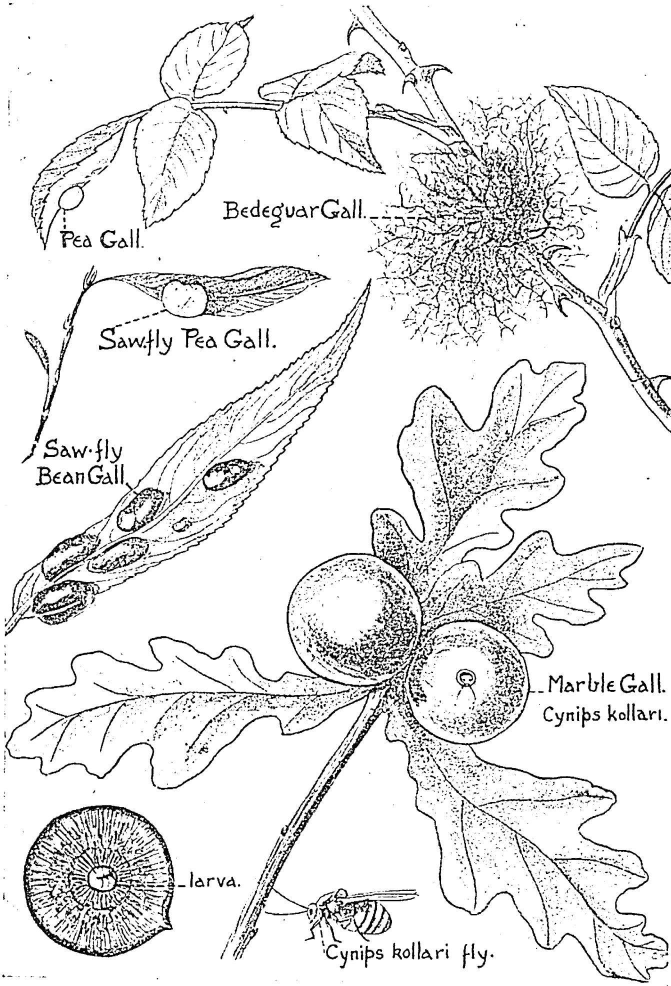


PLATE IV.—Some Common Galls. (Natural size.)
The *Cynips kollari* fly drawn below the oak twig is × 2.

plants, the oak is the most affected by them, over forty kinds of galls being found on it.

The Marble Gall. The Marble or Kollari Gall (formed by *Cynips kollari*) is perhaps the commonest and best known of all; it appears to be specially plentiful on young "oak scrub" (Plate IV.). The Gall Wasps may be seen emerging from these in September or October, though occasionally they remain within the galls until the following May. After emergence they live for some weeks, and each fly lays about 800 eggs; so, even allowing for the many accidents which may befall them, it is no wonder that the galls are plentiful. By the following June the new galls are developing rapidly, one or two together, at the end of a branch or in the axil of a leaf. The gall is at first soft, and yellow or green in colour, but as it matures it darkens and hardens, until by September it is dark brown and woody, and by then the majority of the insects are ready to emerge. It is a strange fact that on examination all these insects are found to be females; no trace of a male has yet been discovered, the generation being, apparently, entirely parthenogenetic. This gall is said to be specially common in the West of England, where, about fifty years ago, it was widely used in the manufacture of a dye for cloth, and it can also be used in the manufacture of ink. The galls contain tannin, which, when exposed to the air, produces, by a process of fermentation, gallic acid, a colourless liquid, and this, when extracted and mixed with a solution of iron sulphate, forms an intense black fluid. The gall, however, which is actually used now in ink-making, is not this British gall, but the Aleppo gall of Turkey and Asia Minor, and also certain Chinese galls.

The darkening of the liquid in the gall by the action of iron on it can be illustrated by cutting a soft gall with a steel knife, when a dark stain results.

The Bedeguar Gall. The Bedeguar Gall, or "Robin's Cushion" (formed by *Rhodites rosae*) is another common gall, found, in this case, on wild or garden rose-trees (see Plate IV.). It is caused by its special Gall Wasp laying several eggs in a leaf-bud, with the result that, instead of forming a normal shoot with leaves, the bud forms a swelling which finally becomes hard, and from which project many

moss-like filaments, beautifully tinted green and red. When cut across, the woody centre is found to have several cavities or cells, in each of which a larva lies. It is in August and September that these galls are most beautiful; later they become dry and brown, though they still contain the larvae, which winter within the galls and pupate in the spring. Both male and female flies are known to emerge, though the former are rare, and it seems probable that parthenogenesis is of general occurrence here also.

Both the Gall Wasps described above have a simple life-history with only a single generation in the year, the most striking feature being the apparently continual parthenogenetic reproduction in the Marble Gall on the oak. Most of the Gall Wasps of the oak, however, go through a curious alternation of two generations in their annual life-cycle—an alternation of a parthenogenetic generation with a normal sexual one—each of the two generations producing a characteristic gall on some part of the tree which is unlike the gall produced by the other generation. These two generations when first described were thought to have no connection with each other, and so each was given a separate generic and specific name. These names are still largely used, though they are now known to refer to different stages, merely, in the life-cycle of one individual; the dual names are still retained in this book, though perhaps the time has come to simplify the nomenclature.

Oak Galls with Alternating Generations. The Gall Wasp which forms the common "Spangle Gall" may be studied as an example of a gall with two alternating generations (Plate V., *A*). The "spangle gall" (formed by *Neuroterus lenticularis*) is extremely common on the under side of oak leaves in late summer, forming little disc-like plates which are thicker in the centre than round the margin, reddish in colour, and with brown, stellate hairs over the surface. In the autumn these galls fall with the leaves to the ground, separating from them as the leaves decay. The Gall Wasps emerge in the spring, and here, as in the Marble Gall, all the emerging insects are females which can lay parthenogenetic eggs. They fly off and pierce the young leaf and flower buds which are just about to start growth. The result is, not the formation of spangle galls again, but of the widely

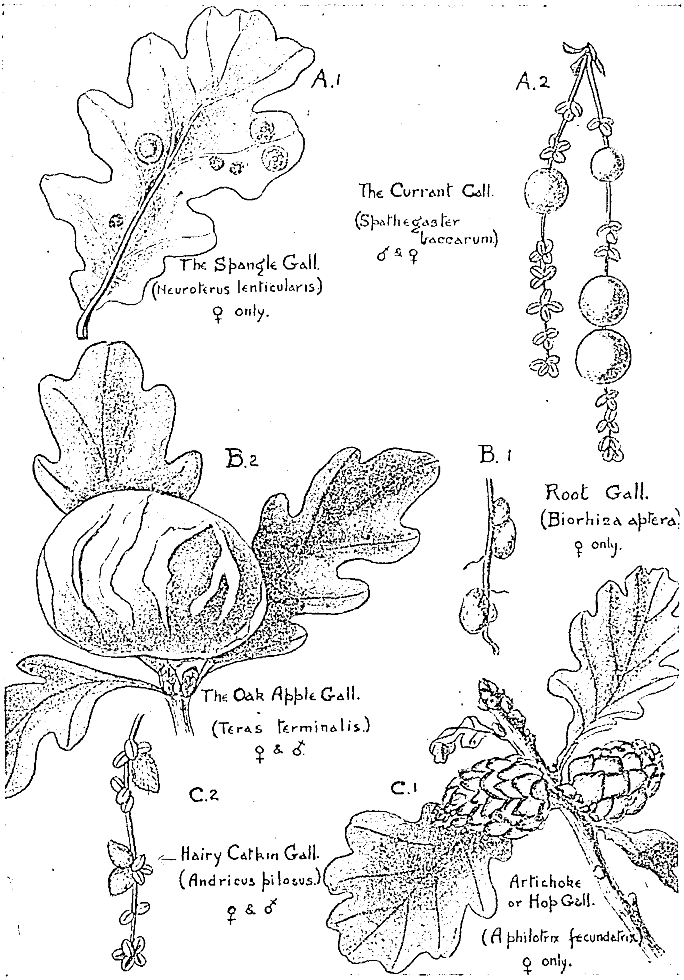


PLATE V.

A_1, The Spangle Gall, or Gall formed by *Neuroterus lenticularis*, the parthenogenetic generation of the fly which, in its alternate, sexual generation, produces the Currant Gall, A_2; B_1, the Root Gall formed by *Biorhiza aptera*, the parthenogenetic generation of the fly which, in the alternate, sexual generation, produces the Oak Apple Gall, B_2; C_1, the Artichoke Gall produced by *Aphilotrix fecundatrix*, the parthenogenetic generation of the fly which, in its alternate, sexual generation, produces the Hairy Catkin Gall, C_2. [The sign ♀ indicates female, ♂ indicates male.]

different "currant galls" (Plate V., A_2) which appear either on the young leaves or on the staminate catkins. The insect within these galls is distinguished as *Spathegaster baccarum*. From the currant galls, in June, emerge both male and female gall insects; the latter lay fertilised eggs in tender young oak-leaves, causing once more the production of spangle galls, and so the cycle is completed.

Similar alternation of two generations—one sexual and one parthenogenetic—and of the alternation of two corresponding different forms of galls, are known in a great many other cases. Some of these are given in the following Table, and are illustrated in Plates V. and VI. Those mentioned are only a few of the many that are known; they are chosen for description here either because they are well-marked, easily recognisable forms, or because they are very frequently found in the South of England.

OAK GALLS WITH ALTERNATING GENERATIONS [1]

GALLS OCCURRING IN LATE SUMMER OR AUTUMN.	GALLS OCCURRING IN SPRING OR EARLY SUMMER.
Neuroterus (♀ only).	Spathegaster (♀ and ♂).
1. The Common Spangle (*N. lenticularis*). Flat hairy discs below the leaves, thickest in the centre, mature in September. Plate V., A_1.	1. The Currant Gall (*S. baccarum*). On the leaf or on male catkins in early spring. Plate V., A_2.
2. The Smooth Spangle (*N. laeviusculus*). Discs pale green, smooth or with hairs only round the central knob, margin incurved. Plate VI., F_1.	2. Schenck's Gall (*S. albipes*). A small egg-shaped outgrowth on the contorted leaf margin; in May. Plate VI., F_2.
3. The Silk-button Spangle (*N. numismatis*). Brown, silky, button-like discs with a central depression, mature in September. Plate VI., G_1.	3. The Blister Gall (*S. vesicatrix*). Inconspicuous green discs, partly embedded in the lower surface of the leaf; with lines radiating from the central knob to the margin. Plate VI., G_2.
4. The Cupped Spangle (*N. fumipennis*). Pale or reddish discs with no central knob, but with margin often slightly curved up; on the surface are delicate brown hairs.	4. The Hairy Pea Gall (*S. bicolor*). Very like the Currant Gall, but lighter coloured and covered at first with short white hairs, found below the leaf in June.
5. The Oyster Gall [2] (*N. ostreus*). Occurs on the mid-rib below a leaf, small and oval, at first enclosed between two brownish scales; pale yellow, often spotted with red; small.	5. April Pea Gall (*S. aprilinus*). Yellow green swellings within the bud scales, very thin walled, may contain more than one larva.

[1] The nomenclature is based on that given in Dr. Adler's *Alternating Generations: A Study of Oak Galls and Gall Flies*, translated into English and edited by C. R. Straton (Clarendon Press, 1894). For explanation of signs see p. 481.

[2] This form should perhaps be removed from the genus *Neuroterus* (see Adler).

OAK GALLS (*continued*)

GALLS OCCURRING IN LATE SUMMER OR AUTUMN.	GALLS OCCURRING IN SPRING OR EARLY SUMMER.
Aphilotrix (♀ only).	**Andricus** (♀ and ♂).
1. **The Truffle Gall** (*A. radicis*). Attached to the root, at first potato-like in form and texture; later dark in colour with lighter fissures, and hard. Each gall has many larval chambers.	1. **The Knot Gall** (*A. noduli*). Little swellings in the shoot or leaf stalk; to be found in June.
2. **The Artichoke or Hop Gall** (*A. fecundatrix*). Large scaly growths, at first green, then brown. Plate V., C_1.	2. **Hairy Catkin Gall** (*A. pilosus*). Oval growths on the anthers of the male flowers. Plate V., C_2.
3. **The Autumn Gall** (*A. autumnalis*). Oval, brown sappy growth inside a bud, depressed at the apex; falls from the bud in October and remains on the ground for eighteen months, the fly emerging in April.	3. **The Woolly or Cotton Gall** (*A. ramuli*). A mass, like cotton-wool, on the leaf or flower bud, each mass containing several galls.
Dryophanta (♀ only).	**Spathegaster** (♀ and ♂).
1. **The Cherry Gall** (*D. scutellaris*). Globular galls below the leaf, yellow and red. Plate VI., D_1.	1. **Purple Velvet Bud Gall** (*S. taschenbergi*). Oval outgrowth on a bud, often on an abnormal bud on the tree-trunk; purple, covered with whitish velvet pile. Plate VI., D_2.
2. **The Scarlet Pea Gall** (*D. divisa*). Occurs on the veins below the leaf, round, flattened, and smooth, at first whitish or red, then brown and hard. Plate IV.	2. **The Red Wart Gall** (*S. verrucosus*). An oval outgrowth, greenish-yellow or reddish, glistening because of the fluid in cells below the rind; it occurs on leaves, shoots, or buds.
Biorhiza (♀ only).	♀ and ♂.
1. **The Root Gall** (*B. aptera*). Usually occur several together on the roots, soft and pink at first, brown and hard later. Plate V., B_1.	1. **The Oak Apple Gall** (*Teras terminalis*). Large, soft throughout at first, fawn colour tinged with rosy pink; usually occur on a terminal bud. Plate V., B_2.
2. **The Kidney Gall** (*B. renum*). Occurs in clusters on the veins beneath a leaf, soft and yellow-green. Plate VI., E_1.	2. **The Pink Wax Gall** (*Trigonaspis crustalis*). Round, soft, red or white galls, occurring usually low down on the trunk on hidden buds or sometimes on young twigs. Plate VI., E_2.

Inquilines in Galls. Some of the *Cynipidae* do not form galls themselves, but lay their eggs in a developing gall formed by a true Gall Wasp. We often find, therefore, the central cavity in the gall inhabited by the gall-maker, and around this, in the wall, several small cavities, occupied by the "guest-wasps" or Inquilines. This is the

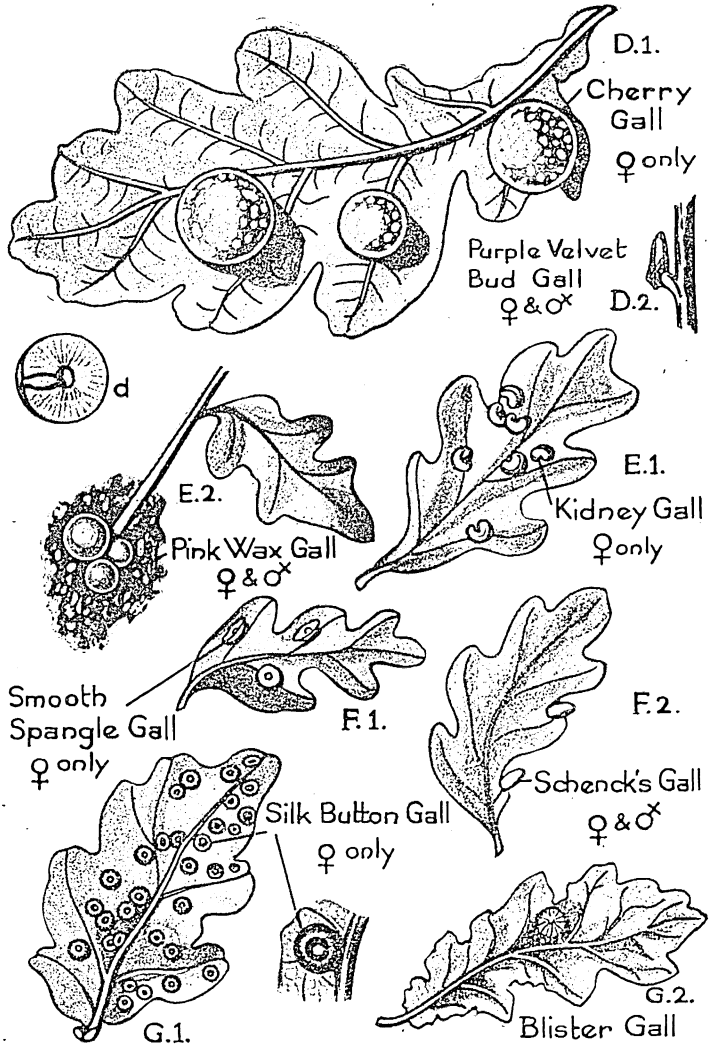


Plate VI.

D_1, E_1, F_1, and G_1, the Galls formed by the parthenogenetic generations of the Gall-flies which in their alternating, sexual generations produce the Galls D_2, E_2, F_2, and G_2 respectively; *d*, a Cherry Gall cut through to show cavity containing the larva.

explanation of the varied larvae sometimes found within the same gall.

Family : ICHNEUMONIDAE (ICHNEUMON-FLIES)

Ichneumon-flies.

Allied to the Gall Wasps are the hosts of parasitic Ichneumon-flies, most of which lay their eggs in Lepidopteran eggs or in or on the body of a caterpillar. The soft, legless larvae live within the host, either until the moment for pupation has arrived, or until the perfect insects are about to break free from the pupae, when the parasites may emerge and pupate outside the body of their victim. One such Ichneumon is *Paniscus testaceus* (Fig. 349), the larvae of which are parasitic in the caterpillars of *Hadena pisi*, one of the Owlet Moths.

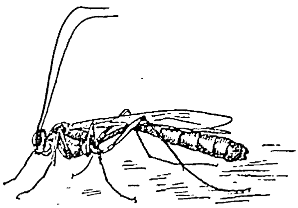


Fig. 349.—*Paniscus testaceus*. A common Ichneumon-fly. (× $\frac{2}{3}$.)

The Ichneumon-flies differ from all other Hymenoptera in having antennae which are long and tapering but are not "elbowed" as they are in ants, bees, and wasps. The hind body is usually narrow at the waist and very mobile, and in the female it bears a long, very effective ovipositor.

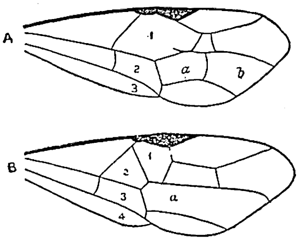


FIG. 350.—Diagram of the wing of an Ichneumonid (*A*), and of a Braconid (*B*).

Family : BRACONIDAE (FALSE ICHNEUMON-FLIES)

False Ichneumon-flies.

The False Ichneumon-flies (*Braconidae*) are very similar to the *Ichneumonidae*, but differ in the nervures of the wing (see Fig. 350), and in the much slighter mobility of the abdomen. The larvae of these forms also live parasitically on Lepidopteran larvae; a very common species is the *Apanteles* (Microgaster) *glomeratus*. This attacks especially the caterpillars of the Cabbage White Butterfly (see pp. 248-9), but it also infests other Lepidoptera.

Classification of the Hymenoptera mentioned in Chapter XXX.

Sub-order: HYMENOPTERA PARASITICA.
Family: Tenthredinidae (the Saw-flies).
Genera. *Lophyrus pini* (the Pine Saw-fly).
Hylotoma rosae (the Rose Saw-fly).
Nematus ribesii (the Currant Saw-fly).
Nematus ventricosus (the Gooseberry Saw-fly).
Nematus gallicola (the "Bean Gall" Saw-fly).
Nematus salicis-cinereae (the "Pea-gall" Saw-fly).
Trichiosoma betuleti (the Hawthorn Saw-fly).
Athalia spinarum (the Turnip Saw-fly).
Family: Siricidae. *Sirex gigas* (the Wood Wasp).
Family: Cynipidae. The Gall Wasps or Gall Flies and Inquilines (for Genera see pp. 483-4).
Family: Ichneumonidae (the true Ichneumon-flies).
Genus. *Paniscus.*
Family: Braconidae (the false Ichneumon-flies).
Genus. *Apanteles* (= *Microgaster*).

PRACTICAL WORK ON SAW-FLIES AND GALL WASPS

1. The larvae of one of the larger saw-flies, the Pine Saw-fly or the Turnip Saw-fly, should be searched for, and, when found, kept in a glass-covered breeding-box with plenty of its food plant. Its metamorphosis can then be watched. Careful sketches should be made of the different stages in its life-history.

Other saw-flies which are found may be identified by reference to P. Cameron's *Monograph on British Phytophagus*[1] *Hymenoptera.*

2. A few Marble Galls (*Cynips kollari*) should be collected in the autumn and kept in a covered glass vivarium until the Gall Wasps emerge, when they should be carefully studied and sketched.[2] They should then be placed on an oak twig surrounded by a muslin bag, or better still on an oak sapling grown in a pot, which can be enclosed in a light wooden frame covered with muslin over the sides and with glass at the top. The insect may then be seen piercing the base of a bud and laying its eggs there; the gall will first become apparent in the following May.

3. Other Oak Galls with a more complicated life-history should also be collected, and the alternation of generations in them

[1] *Phytophagus* = plant-eating.

[2] Some will emerge in October or November, but others will remain in the gall until the spring.

carefully followed. For their investigation it is well to have a number of little oak trees, about six years old, in pots, with movable covering-frames as described above, and those gall insects should be first chosen for study which will lay their eggs on the leaf-buds or bark of such young trees. The Spangle Gall would be a good type to begin with. The galls should be collected in the autumn after the leaves have fallen from the trees and the galls are becoming detached from the leaves. They should be laid on a pot half full of damp sand or earth, covered with moss, and the pot then sunk in the earth out of doors, and covered with the muslin-covered frame ; under these conditions the larvae will winter within the gall, the flies emerging probably in April. As soon as they appear, the flies should be transferred to the young oak saplings, and watched closely, for they will almost immediately begin to lay their eggs in the oak buds, piercing a hole with the long ovipositor characteristic of Gall Wasps. The buds pricked should be marked, and a watch kept on them as they unfold. It will be found that in a large number there is no result, the egg having apparently perished ; but in a few there will appear on the leaf a new gall, the Currant Gall, which is the second generation of the Spangle Gall. If these Currant Galls are collected in June and carefully kept fresh on damp sand, the male and female flies of this second generation will be obtained, and the females may be watched later on, crawling over the young plant and laying their eggs in the under surface of a leaf, as a result of which new Spangle Galls will begin to appear in three or four weeks' time.[1]

4. Any other plant Galls found may be identified by reference to *British Plant Galls*, by E. W. Swanton ; the life-histories of the insects causing them should be worked out as far as possible.

[1] For these suggestions as to the rearing of Gall Wasps I am indebted to Dr. Adler's most interesting book on *Oak Galls and Gall Flies*, in which details as to the life-histories of all the common oak galls are given.

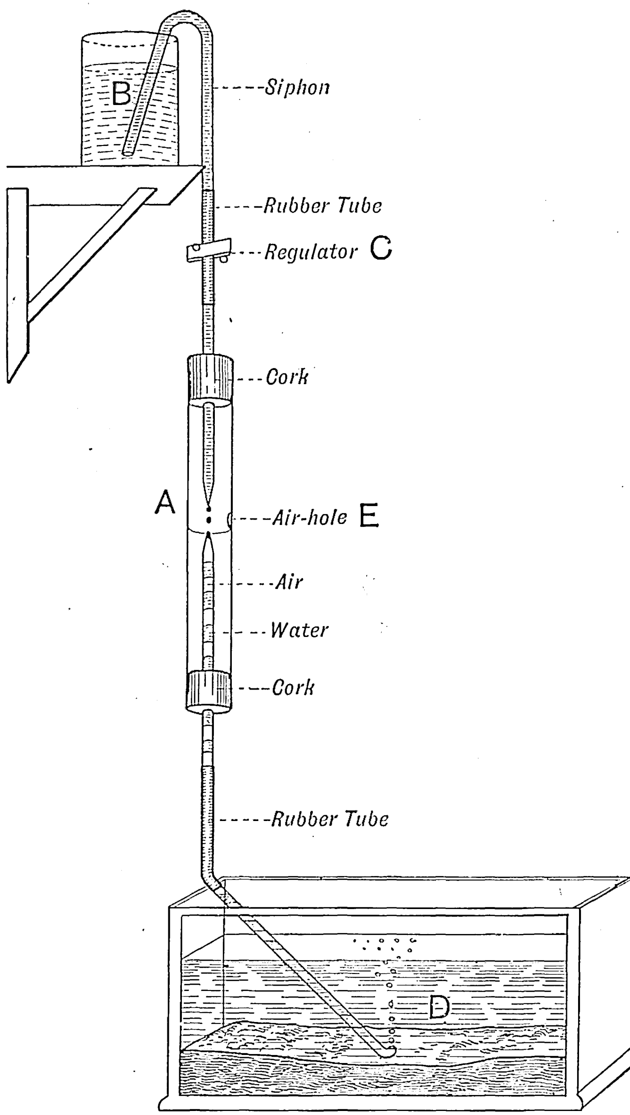


FIG. 351.—Diagram of a simple form of aerating apparatus for a tank.

APPENDIX A

ON HOW TO AERATE AN AQUARIUM

(From *A Handbook to Marine Aquaria at the Horniman Museum*, by kind permission of the L.C.C.)

A SUPPLY of oxygen for breathing purposes is as necessary for aquatic animals as for ourselves. Aquatic animals make use of the oxygen which is held in solution in the water, and it is essential to keep them well provided with it if they are to remain healthy. The seaweeds provide a certain amount of this oxygen, but in an aquarium some additional means of properly oxygenating the water is usually necessary. In default of anything better a glass syringe (metal should not be used) may be used to discharge water from a height into the tank in order to fill it with air bubbles, and this may be done two or three times during the day; or the water may be occasionally briskly stirred up with a glass rod in order to bring about a circulation in the tank, care being taken that the sand is not disturbed. A much more satisfactory and yet simple piece of apparatus for providing a continuous circulation and aeration of the water may be made quite cheaply, as in the accompanying illustration.

"A" is a piece of half-inch glass tubing of about four inches in length, with an air-hole ground through at E. Two pieces of glass tubing, each drawn out to a point in a gas flame, are fitted into corks, one at each end of the half-inch glass tube, and are arranged so that their points are about half an inch apart. A piece of rubber tubing connects the lower of these two tubes to another glass tube which runs to the centre of the bottom of the tank D. The upper of the two pointed glass tubes is also connected by a rubber tube with a bent glass tube, the siphon, which is passed into a jar B standing upon a shelf some three or four feet above the tank. C is a regulator, made of two pieces of wood joined at opposite ends by screws which can be tightened or loosened at will in order to regulate the amount of water passing

through the rubber tube. The jar B is filled with water from the tank and the whole apparatus placed in the position shown on the illustration. The lower piece of indiarubber tubing is pinched with the fingers and air is then sucked through the air-hole to start the water running through the siphon, the regulator being adjusted so that the water runs only at a fast drip. As each drop falls it should cause a bubble of air to be carried down the lower tube into the tank. By careful adjustment the apparatus may be made to act so that the jar only requires filling twice a day. A gallon jar should be used for, say, a ten-gallon tank.

Some animals, such as the common anemone, may be kept without continuous aeration, and others with an occasional syringing, but all the animals will be better and healthier for good aeration.

ANOTHER METHOD OF AERATION

Readers are also referred to the excellent method of aeration described by Dr. T. A. Stephenson and Mr. W. E. Evans in "Discovery" for February 1926. In their apparatus a water-tap that can be kept very slowly running and a water outlet are needed, but, given these, the apparatus is not difficult to set up.

APPENDIX B

ARTIFICIAL SEA WATER[1]

If real sea water cannot be obtained, artificial water may be made as follows and will act as an excellent substitute.

Ingredients

$46\frac{1}{2}$ oz. salt (ordinary kitchen block salt).
$3\frac{1}{2}$ oz. sulphate of magnesium.
$5\frac{1}{4}$ oz. chloride of magnesium.
2 oz. sulphate of potassium.
$13\frac{1}{4}$ gallons pure fresh water (but tap water will do).

Dissolve each ingredient separately in a portion of the water, then mix all these solutions and stir thoroughly. After a few days, add some living seaweed, and let the mixture stand for a few weeks in a good light. Add a small sea creature (*e.g.* a prawn) to observe whether the artificial sea water is "good" before introducing the other creatures.

[1] These directions were kindly given to me by the Zoologist of the Horniman Museum, Forest Hill, S.E.

APPENDIX C

HOW TO MAKE WOODEN FORCEPS[1]

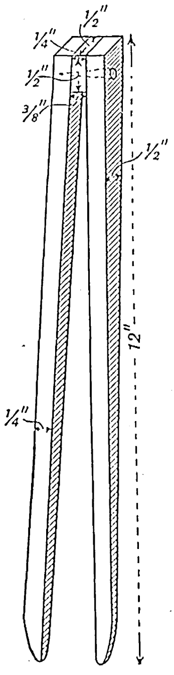


FIG. 352.

Use. For picking up particles of meat or any debris from the water of a deep tank, or for holding a scrap of meat when feeding its inmates.

Materials needed. Two strips of $\frac{1}{2}'' \times \frac{1}{4}''$ "strip wood," length as required for aquarium (12″ is a useful size). One block of wood $\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{3}{8}''$, 1 screw and 2 nails about $\frac{7}{8}''$ long.

Method. 1. Shave one end of each strip to a convenient shape (see Fig. 352); leave the inner surface of each strip flat, shaving off the outer surface, otherwise the points of the two will not meet. Rub the shaped ends with glass paper so that they are quite smooth.

2. Shape the small block so that its upper end measures only $\frac{1}{4}''$ across, the lower end being $\frac{3}{8}''$ across. This produces a slight wedge-shaped joint that gives play to the forceps.

3. Fasten the wedge between the two strips by a screw from the middle of one side and by two small nails from the other, in order to keep the parts from twisting on the screw.

[1] I am indebted to Miss Hilda Rendle for this description and figure.

APPENDIX D

SUBTERRARIUM FOR BEETLES, ETC.[1]

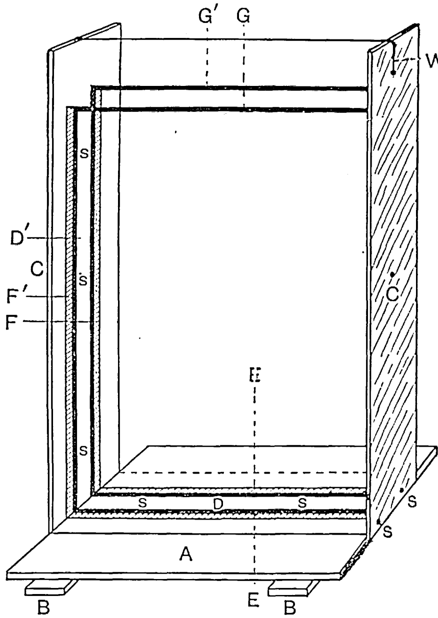


FIG. 353.—View of Subterrarium.

G′, *G*, sheets of glass; *s*, *s*, screws; *W*, wire or strap; for other letters see text.

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[1] Designed by Mr. Hugh Main and described here by his kind permission.

Materials needed

Wood for Framework.
A. Base—$9'' \times 5'' \times \frac{1}{2}''$.
B. Two base supports—$5'' \times 2'' \times \frac{1}{2}''$.
C. Two sides—$14\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{3}{8}''$.
D. One separating basal piece—$8'' \times \frac{1}{2}'' \times \frac{1}{2}''$.
D′. Two vertical separating pieces—$11\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{1}{4}''$.
E. Two basal supports for glasses—$8'' \times \frac{1}{2}'' \times \frac{1}{2}''$.
F. Four vertical side supports for glasses—$12'' \times \frac{1}{2}'' \times \frac{1}{4}''$.
G. One cover—$8\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{1}{2}''$.

Glass. Two pieces of glass (G, G′ in Fig. 353) $12'' \times 9''$. The glass should be thick—technically called 21 oz. glass.

Other Materials. About 40 small screws, 2 small screw-eyes, a piece of stout wire about 1 ft. long, 2 small staples, a little paint, and a few nails.

Procedure

1. Nail the two base supports below and across the narrow ends of the base.

2. Screw the sides to the centre of the outer ends of the base so that they stand vertically.

3. Screw the single basal and two vertical separating pieces across the centre of base and up the sides respectively.

4. Put the glass of one side against these separating pieces and screw on the basal and vertical side supports for the glass, leaving just enough room for the glass to slide up and down easily in the grooves—it can then be readily removed for cleaning when setting up the cage again after use. Repeat with the glass and supporting pieces of the other side.

5. Trim and adjust the cover so that it just fits into the space between the glasses at the top and fix down with screw-eyes inserted into the ends of the separating pieces. A half turn of the screw-eye should hold the cover firmly in place, a very necessary precaution, since many beetles are both strong and active.

6. Removing the cover, press down between the glasses layer after layer of clean-sieved soil ("top-spit") to within about 3 inches of the top. Damp the soil, and keep it always damp, but not wet.

7. Fix the wire across the top and down the sides, holding it securely with the staples. It will then act as a convenient handle and also hold the sides together. (A leather strap and buckle fixed across are better still, for they can be undone and put and left at the sides when filling with earth.)

8. Introduce the creatures whose life history it is desired to study. Protect from the sun if necessary. Fig. 354 is a photograph of a completed case in use.

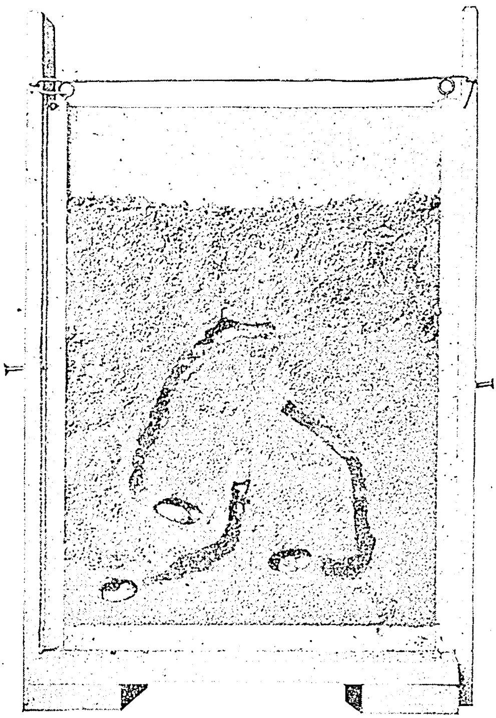

FIG. 354.—Subterrarium with larvae and pupae of *Geotrupes typheus*, a Dor-beetle, in it. (Photo by Mr. Hugh Main.)

APPENDIX E

HOW TO MAKE A FORMICARIUM[1] FOR ANTS

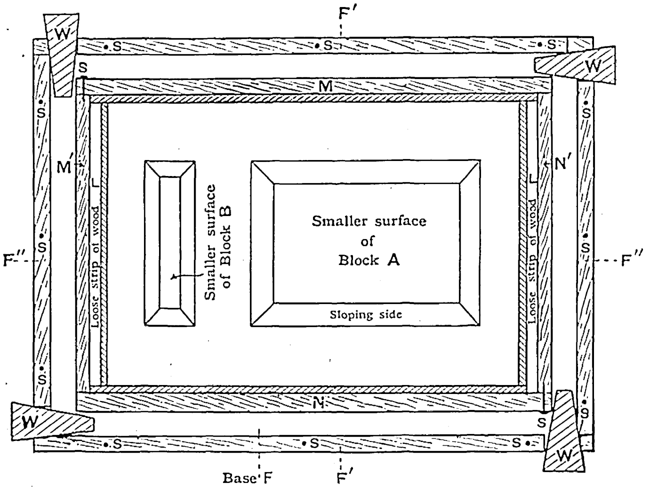

FIG. 355.—Ground Plan of "Mould" for making a *Formicarium*. (The "barred" strips inside M, M′, N, N′ are loose strips of glass. For letters see description in text. *s*, *s*, are screws.)

MATERIALS NEEDED.

Wood for Mould.

2 *strips* $11\frac{3}{8}'' \times 1\frac{5}{8}'' \times \frac{3}{8}''$ (M and N in Fig. 355)
2 *strips* $6'' \times 1\frac{5}{8}'' \times \frac{3}{8}''$ (M′ and N′).
2 *strips* $5\frac{6}{8}'' \times 1\frac{5}{8}'' \times \frac{3}{8}''$ (L and L).
1 shaped *block*, upper surface $4\frac{2}{8}'' \times 3''$.
lower ,, $5\frac{6}{8}'' \times 4''$.
thickness of block $1\frac{1}{4}''$.
1 shaped *block*, upper surface $3'' \times \frac{1}{2}''$.
lower ,, $4'' \times 1\frac{1}{4}''$.
thickness of block $1\frac{1}{4}''$.

[1] This case may be used also as a home for Millipedes, Wood-lice, etc.

Wood for Outer Frame.	*Base* (F) about $13\frac{1}{2}'' \times 9'' \times \frac{3}{8}''$. 2 *strips*, each $12\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{3}{8}''$ (F′ F′). 2 *strips*, each $8\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{3}{8}''$ (F″ F″). 4 *wedges* to fit in at W.
Glass.	1 *piece* to fit over base F between F′ and F″. 4 *strips* to line upright sides N, N′, M, M′ when fitted together as directed below. 1 *piece* of thick glass $5\frac{6}{8}'' \times 4''$ to form a cover.
Other Materials.	1 tin baking tray about $12'' \times 8'' \times 2''$. 2 or 3 lbs. of plaster of Paris. 16 small screws, 2 screw-eyes, Brunswick black, vaseline, seccotine.

PROCEDURE.

Put all the pieces in position as in the Figure; be sure the mould is firmly wedged.

Vaseline the blocks A and B where not touching the glass. A thin smear of seccotine on the lower surface of each will help to prevent them from shifting on the glass.

When all is ready, mix the plaster of Paris; put a little cold water into an old enamel bowl and add the dry powder, a little at a time, stirring with a stick until the plaster is quite smooth and of the consistency of a thick cream. Pour quickly into the mould, steadying the blocks at first if necessary to prevent shifting. Fill the mould a little above the top of the wooden strips; after a minute, scrape off superfluous plaster with a straight piece of wood or metal (*e.g.* a ruler).

Leave the plaster of Paris to set (this will take about 2 hours).

Meanwhile paint the baking tin with Brunswick black and let it dry. When the plaster is firmly set, take out the wedges and pull away the wood and glass strips from round the plaster-cast, which now lies upside down on the glass sheet; carefully loosen and invert it and remove the wooden blocks A and B. To do this it is usually necessary to screw in a screw-eye at each end of a block and pull it upwards out of the plaster.

Finally, stand the complete plaster-cast in the baking tin with cavities A and B uppermost and pour in more freshly mixed plaster of Paris, filling the space between the mould and the sides of the tin to a level not quite so high as that of the "cast." Now fill the cavity B with water and put earth into cavity A, and the Terrarium is ready for the ants or whatever creatures you wish to keep in it. Cover with the heavy slab of glass.

INDEX

The names of Phyla, Classes, Orders, etc., are given in italics.
Figures in italics indicate that the reference relates to systematic position only.
Asterisks indicate illustrations.

THE END

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